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Exercise 3 : Foundation Builder

This sample book is prepared from the book **"Foundation Course in Physics Class 9 with Case Study Approach for IIT JEE/ NEET/ Olympiad - 6th Edition".**

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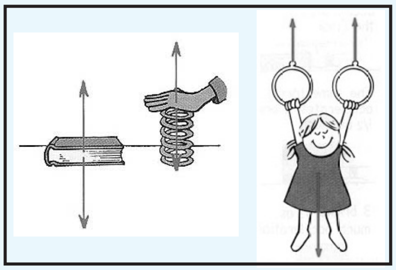
Chapter 2

Force and Laws of Motion

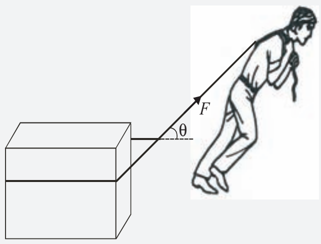
Learning Objectives

- Force
- Balanced and Unbalanced Force
- Ist Law of Motion
- Inertia and Mass
- IInd Law of Motion
- IIIrd Law of Motion



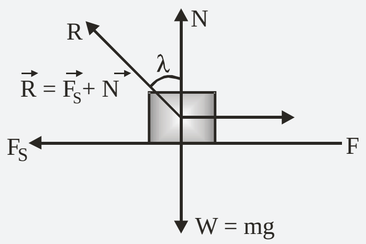
Exam Mirror

- Components of Force
- Momentum
- Impulse



Critical Concepts

- Conservation of Momentum
- Friction



FORCE

In our daily life we find that a body at rest can be moved and one that is moving can be stopped. The doors and windows of a house are pushed to open and pulled to shut them. In games like cricket, hockey and football, players on the ground sometimes stop a moving ball or manage to deflect it to some other direction. The boatsman pulls a boat with a rope in order to bring it to the shore or pushes it to get it into the water. *This push or pull is called the force in everyday language.*

Force is a vector quantity (it has both magnitude and direction). There must be a net force (unbalanced force) acting on an object for the object to change its velocity (either magnitude and/or direction), or to accelerate.

If we want the car to stop, we have to do something to it. That is what our brakes are for : to exert a force that decreases the car's velocity. In a basketball, a player launches a shot by pushing on the ball.

Thus it can be said that the force is a physical influence which can change the state of motion or state of rest of a body. A force can change the direction of motion of a body.

A force is that physical quantity which tries to change or changes the state of rest or of uniform motion of a body.

To obtain a complete information about the force acting on an object one should know

(i) the point of application of force

(ii) the magnitude of force

(iii) the direction in which the force acts.

Units of Force

(i) The **S.I. unit** of force is newton.

One newton is the force which when acts on a body of mass 1 kg, produces an acceleration of 1 ms^{-2}.

i.e., 1 newton (N) = 1 kg × 1 ms^{-2}

(ii) In **C.G.S. system,** the unit of force is dyne.

One dyne is the force which when acts on a body of mass 1 gramme, produces an acceleration of 1 cm s^{-2}.

i.e., 1 dyne = 1 g × 1 cm s^{-2}

(iii) Units of force in terms of force due to gravity

In MKS system, the unit of force is the kilogramme force (kgf).

One kilogramme force is the force due to gravity on 1 kilogramme mass.

Thus, 1 kgf = force due to gravity on 1 kg mass = 1 kg mass × acceleration due to gravity m s^{-2} = g newton

Since the average value of g is 9.8 ms^{-2}

$\therefore$ *1 kgf = 9.8 newton (or 9.8 N)*

Some Common Mechanical Forces

(i) Contact forces: When a body *M* is in contact with body *N*, *M* can exert force on *N* and *N* can exert a force on *M*. These forces are called contact forces. Push or pull by a person, force by wind, force by a weight on the head of a porter, frictional force, normal reaction force, tension in strings, forces exerted during collision are the examples of contact forces.

Practical examples

(a) The pulling of a trolley by a coolie.

(b) The pulling of a cart by a horse.

(c) The pushing of a door to close it.

(d) The stretching of a spring by suspending a load.

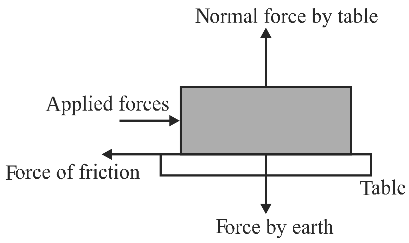
(e) The squeezing of a gum or toothpaste tube to extract the gum or toothpaste.

(ii) Tension: This is a special type of elastic recoil, resulting from stretching something. In a tug-of-war, the rope is under great tension, so it pulls back on the teams at the opposite ends. The spring scale is actually a tension-measuring device. The harder you pull on both ends of the spring, the more it stretches, and the harder it pulls back.

(iii) Viscous drag: Anything moving through a liquid or gas feels a retarding, friction-like force. That is why a boat needs an engine, why we cannot swim fast enough to get into the Olympics, why automobiles are streamlined, and why a parachute is advisable if we plan to fall out of an airplane.

(iv) Normal force: If contact force between the bodies is perpendicular to the surface in contact, the force is known as normal force. Let us consider a block on a table. The table pushes the block upwards and block pushes the table downwards. Then forces are perpendicular to the surfaces of block and table. Thus the table applies a normal force on block in the upward direction and block applies a normal force on table in downward direction.

(v) Friction: Two bodies placed in contact can also exert forces parallel to the surfaces in contact, such a force is called force of friction or simply friction. Suppose a body is placed on the table. Following three forces acts on it.



(1) Force by earth in downward direction

(2) Normal force due to table in upward direction.

(3) Applied force towards right.

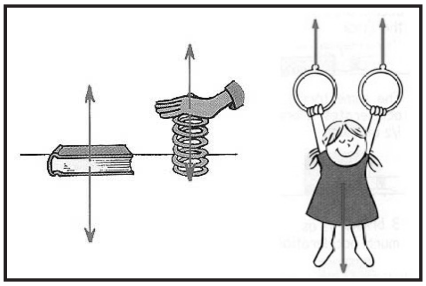
Body is not moving, so all the forces must be balanced, normal force due to table and force by earth balanced each other. To balance the applied force there must be an equal and opposite force. This force is known as force of friction. If we increase the applied force the body is still at rest. It means force of friction is also increased till it is balanced by the applied force. The force of friction is self adjusting force. On increasing the applied force, the force of friction will increase up to a limit . It is known as limiting friction. After it, on increasing the applied force, the body will start to move.

BALANCED AND UNBALANCED FORCES

One effect of a force is to alter the dimension or shape of a body on which the force acts; like by loading a spring, there occurs an increase in its length. By hammering a small piece of silver sheet, thin foil is made. The steam pushing out from a pressure cooker occupies a large volume. On pressing a piece of rubber, its shape changes. In a cycle pump, when the piston is lowered, the air is compressed to occupy less volume. Another is to alter the state of motion of the body. A player applies force with a hockey stick to change the speed and direction of motion of a ball. When more force is applied on the pedal by a cyclist, speed of the cycle increases. In many situations we may find that a body remains at rest or moves uniformly even if it is acted on by a force ! For example try to push a heavy stone or a heavy iron safe, probably we may not be able to move it. Does it mean that something is wrong with the definition of force ? What happens actually is that there exists another force which is acting on the body in a direction opposite to your push and exactly compensating it. In effect there is no net force acting on the body. This force which we have not taken into account is the force of friction.

When several forces act on a body simultaneously, their effects can compensate one another with the result there is no change in the state of rest or motion. When this is the case, the body is said to be in **equilibrium**. Equivalently, one can say that the net force or resultant force acting on the body is zero for balanced forces.

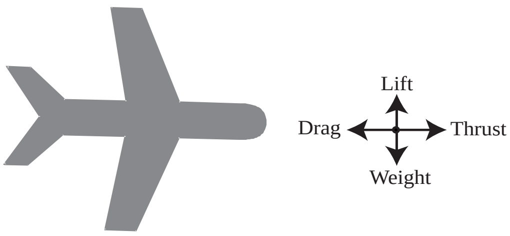
If a set of forces acting on a body produces no acceleration in it, the forces are said to be ***balanced***.



Balanced forces

An object in equilibrium may or may not be at rest. A parachutist, descending at constant speed, is in equilibrium. His weight is just balanced by the viscous drag on the parachute-which is why he put it on in the first place. A heavier parachutist falls a little faster, his speed increases until the viscous drag just balances his weight.

Balancing the vertical forces is not enough to produce equilibrium. An airplane traveling at constant speed, as in figure, is in equilibrium under the influence of four forces, two vertical and two horizontal.



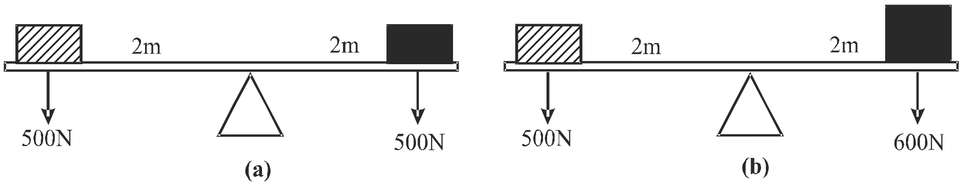
Vertical force: Weight or gravity (down) is just balanced by the lift produced by the flow of air across the wing.

Horizontal force: Viscous drag is just balanced by the thrust of the engines. Both the vertical and the horizontal velocities are constant.

When the resultant force or net force acting on a body is not zero we say that it is acted on by an unbalanced force. A net or unbalanced force when acts on a body it changes its state of rest or uniform motion.

If a set of forces acting on a body produces non-zero acceleration in it, the forces are said to be **unbalanced.**

To imagine unbalanced force, imagine see saw. If the people on either side push down with the same force, they cancel each other. The see-saw is balanced and does not move [(fig. (a)]. In fig (b), there is an unbalanced force of 100N. This moves the see-saw down at one end.

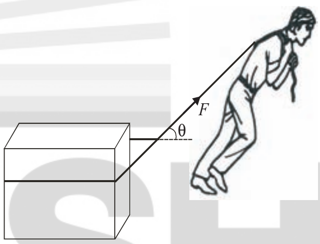


Resultant or Net Force

If a single force acting on a body produces the same acceleration as produced by a number of forces then that single force is called the resultant force of these individual forces.

Components of a Force

The crate in figure is being dragged along the floor by means of a rope, which is not horizontal. The rope makes an angle θ to the floor.



The tension in the rope, acting on the crate, does two things to it. First, it drags the crate across the floor. Second, it tends to lift the crate off the floor. The smaller the angle θ, the larger the effective force that is dragging the crate, and smaller the effective force that is lifting it. When θ = 0°, the entire force is dragging and there is no lifting at all. Conversely, when θ = 90°, the entire force is lifting the carate.

How can you find out how much force is being used to drag the crate ? Force is a vector, and it obeys the same mathematical rules as velocity vectors and displacement vectors. The dragging force is the component of the tension in the rope acting parallel to the floor, that is, the horizontal component

$$F_{horizontal} = F \cos \theta$$

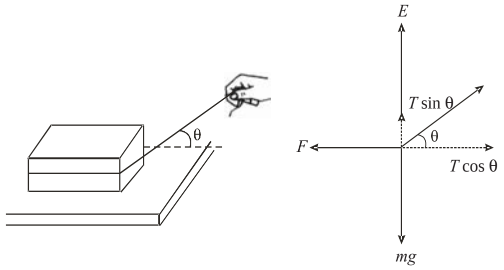
Similarly, the component of the force tending to lift the crate is, the vertical component and is given by

$$F_{vertical} = F \sin \theta$$

Equilibrium of a Body with Several Forces

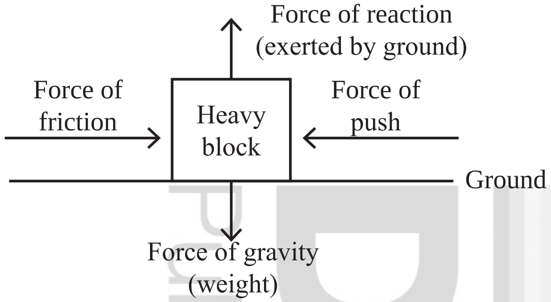
For the purpose of making a complete analysis of the forces acting on an object, a vector diagram is a useful device.

A vector diagram showing the forces on a brick (figure) being dragged along a tabletop. Four forces act: gravity (weight), friction, elastic recoil of the tabletop, and tension in the cord. Each force is represented by a vector, drawn at the correct angle and with its length proportional to the force. For the purpose of analysis, all vectors are represented by components along a pair of axes perpendicular to each other. In this case, we select to use horizontal and vertical axes, since three of the forces are already on these axes. To do the analysis, we have to resolve the tension vector into its components on the vertical and horizontal axes. Then we can write two equations: one says that there is no net vertical force, and the other says that there is no net horizontal force.



CASE STUDY-1 : Understand Balanced and Unbalanced Forces

If the resultant of all forces acting on a body is zero, i.e., $\Sigma F = 0$, the forces are called balanced forces. And if $\Sigma F \neq 0$ the forces are called unbalanced forces. Unbalance of forces produce motion in a stationary body or stop a moving body. Balanced forces can change the shape of a body not state of rest or of motion.



CASE - I: Maintaining the state of rest or of uniform motion of a body. It is when the body is under the action of balanced forces.

CASE - II: Unbalanced force can change speed or direction of motion of a body.

CASE - III: To accelerate a body always require an unbalanced force.
i.e., $\Sigma F \neq 0$ so $\Delta v \neq 0$
$\therefore$ $a \neq 0$

CASE - IV: If no net force acts on a body then change in velocity $\Delta v = 0$
$\therefore$ acceleration, $a = 0$

CASE - V: If a number of forces $\vec{F}_1, \vec{F}_2, \vec{F}_3$.......... act on the body then it is in balanced or equilibrium state, when $\vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ... = \vec{0}$

Think Out of the Box

Q 1. Why the shape of a balloon changes, when it is pressed between hands?

[**Hint :** Balanced forces]

Q 2. If one of the teams suddenly releases the rope in a tug of war, the other team falls backwards. Why?

[**Hint :** Unbalanced Forces]

Q 3. If we release the book from our hand, it falls to the ground. Which force acts on it?

[**Hint :** Unbalanced force]

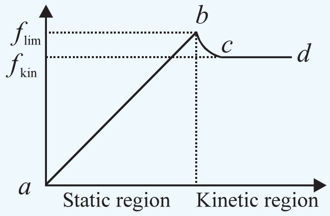
CONNECTING TOPIC

Friction

Friction is a resistance to the relative motion between two objects in contact (in case of solid objects) or the body and its surroundings (in case object is moving in a fluid).

Static Frictional Force

When there is no relative motion between the contact surfaces, frictional force is called static frictional force. It is a self-adjusting force, it adjusts its value according to requirement. In the example static frictional force is equal to applied force. Hence one can say that the portion of graph *ab* will have a slope of 45°. ($f_s \le \mu_s N$)

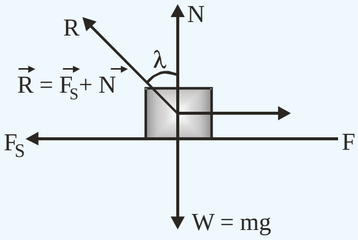


Limiting Frictional Force

This frictional force acts when body is about to move. This is the maximum frictional force that can exist at the contact surface. We calculate its value using laws of friction.

Kinetic Frictional Force

Once relative motion starts between the surfaces in contact, the frictional force is called as kinetic frictional force. The magnitude of kinetic frictional force is also proportional to normal force.



Angle of Friction (λ)

The angle of friction is the angle which the resultant of limiting friction f_L and normal reaction N makes with the normal reaction. It is represented by λ.

$$\tan\lambda = \frac{F_L}{N} = \frac{\mu N}{N} = \mu$$

Angle of Repose (θ)

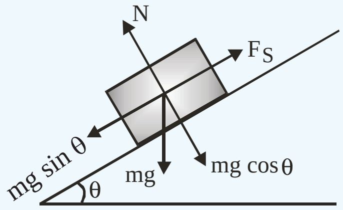
If a body is placed on an inclined plane and if its angle of inclination is gradually increases, then at some angle of inclination θ the body will just on the point to slide down. This angle is called angle of repose (θ).

$\therefore \quad F_L = mg\sin\theta$

and $\quad N = mg\cos\theta$

So, $\frac{F_L}{N} = \tan\theta \quad \left[\because \frac{F_L}{N} = \mu\right]$

or $\quad \mu = \tan\theta$



Let's Connect

1. The coefficient of static friction between two surfaces depends upon
   (a) the normal reaction
   (b) the shape of the surface in contact
   (c) the magnitude of applied force
   (d) None of these

2. If the applied force is doubled, then coefficient of friction is
   (a) halved (b) tripled (c) doubled (d) not changed

Solutions:

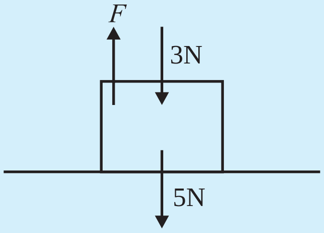
1. **(a)** Coefficient of static friction = $\frac{\text{force of friction}}{\text{normal reaction}}$

Therefore, coefficient of static friction depends upon the normal reaction.

2. **(d)** Coefficient of friction is independent of applied force.

Illustration 1 :

A block of weight 5N is placed on a horizontal table. A person push the block from top by exerting a downward force of 3N on it. Find the force exerted by the table on the block.



Solution :

There are three forces on the body:

(i) 5N, downward by earth

(ii) 3N, downward by the person

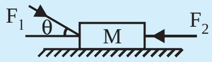
(iii) F, upward by the table

As the block is at rest, the resultant force on it must be zero. The total downward force is 5N + 3N = 8N.

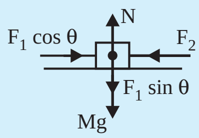
Hence the upward force F should be 8N. So the force exerted by the table on the block is 8N in the upward direction.

Illustration 2 :

If the body is in equilibrium then find F_2 and normal reaction.



Solution :



In horizontal direction

$F_1 \cos\theta - F_2 = 0 \Rightarrow F_2 = F_1 \cos\theta$

In vertical direction

$N - F_1 \sin\theta - Mg = 0 \Rightarrow N = F_1 \sin\theta + Mg$

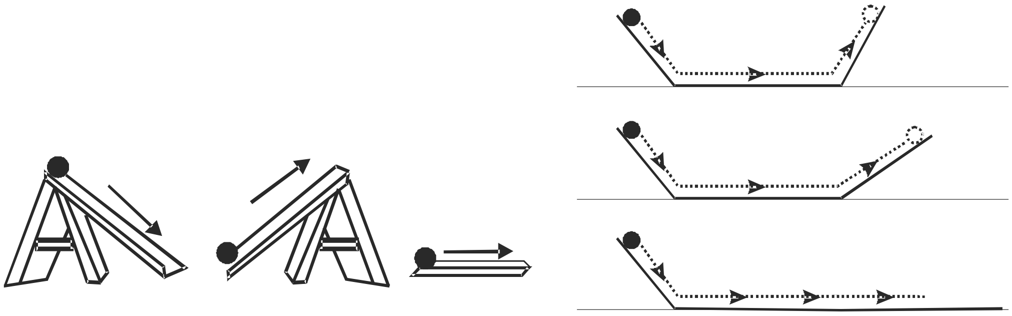
FIRST LAW OF MOTION

According to this law, *an object continues in a state of rest or in a state of motion at a constant speed along a straight line, unless compelled to change that state by a net force*. In other words, if a body is in a state of rest, it will remain in the state of rest and if it is in the state of motion, it will remain moving in the same direction with the same velocity unless an external unbalanced force is applied on it. This law is also called **law of inertia.** It gives qualitative definition of force.

Galileo studied the motion of objects on an inclined plane. Objects moving down an inclined plane accelerate, while those going up the plane suffer retardation. Motion on a horizontal plane is an intermediate situation. Galileo concluded that an object moving on a horizontal plane must neither have acceleration nor retardation, i.e. it should move with constant velocity.

Another experiment of Galileo leading to the same conclusion involves a double inclined plane. A ball released from rest on one of the planes rolls down and climbs up the other. If the two planes are not very rough. the final height of the ball is nearly the same (a little less but never greater) as the initial height. In the ideal situation, when friction is completely eliminated, the final height of the ball should equal its initial height ?

If now the slope of the second plane is decreased and the experiment repeated, the ball will still reach the same height, but in doing so it will travel a longer distance. In the limiting case, when the slope of the second plane is zero (i.e. it is a horizontal plane) the ball travels an infinite distance. In other words, its motion will never cease. This is, of course, an idealised situation. In practice, the ball does come to a stop after in motion continues to move with uniform velocity. This property of every object in nature is called inertia. Inertia means ‘resistance to change]. A body does not change its state of rest or of uniform motion, unless an external force compels it to change that state.



(a) (b)

INERTIA AND MASS

A greater net force is required to change the velocity of some objects than of others. The net force that is just enough to cause a bicycle to pick up speed will cause an imperceptible change in the motion of a freight train. In comparison to the bicycle, the train has a much greater tendency to remain at rest. Accordingly, we say that the train has more inertia than the bicycle. Quantitatively, the inertia of an object is measured by its mass. Inertia is the natural tendency of an object to remain at rest or in motion at a constant speed along a straight line. The mass of an object is a quantitative measure of inertia. *The greater the mass, the greater is the inertia of body*. The definition of inertia and mass indicates why Newton's first law is sometimes called the law of inertia.

Although the law of inertia was first clearly enunciated by Galileo, the English natural philosopher Issac Newton (1642-1727) incorporated the law into the solid logical basis on which he founded the science of mechanics in his great 1687 work, commonly called Principia.

Too little force, too little time to overcome "inertia" of tableware.

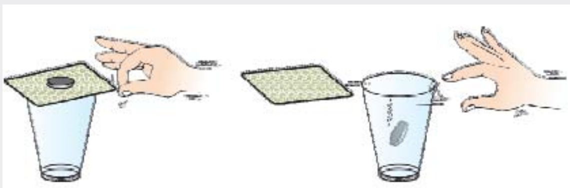
Let's Do Activity

Aim : *To understand law of inertia by using glass and coin.*

Requirement : *Glass, stiff card, coin, table etc.*

Procedure : ☞ *Put the coin on a stiff card covering an empty glass on a table.*

☞ *Do a quick flick to the card with your fingers.*



Observation : ☞ *The card fly away and the coin will fall vertically into the glass due to inertia.*

☞ *This is due to the fact that the inertia of the coin tries to be in its state of rest.*

Conclusion : *We understand Law of Inertia.*

Types of Inertia

1. **Inertia of rest :** *The tendency of the body to continue in state of rest even when some external unbalanced force is applied on it is called inertia of rest.*

   Examples:

   (i) When a carpet is suddenly jerked the dust fly off, because due to the sudden moment the carpet moves but the dust on account of inertia of rest is left behind.

(ii) The passenger standing in a bus tends to fall backwards when the bus suddenly starts, this is because his feet are in direct contact with the floor of the bus and the friction at the contact is high this friction does not allow the feet to slip on the floor, the feet therefore move forward with the floor and the upper part of the body is still at rest for a while thus the passenger gets a jerk.

(iii) On shaking a tree, the fruits fall down. The reason is that when the stem or branches are shaken, they come in motion while the fruits remain in the state of rest due to the inertia of rest. Thus the fruits get detached from the branches and fall down due to the pull of gravity.

2. **Inertia of motion :** *The tendency of the body to continue in its state of motion even when some unbalanced force is applied on it is called the inertia of motion.*

Examples :

(i) It is dangerous to jump out of a moving vehicle (bus/train), because the jumping man, who is moving with the high speed of the vehicle would tend to move with the high speed of the vehicle. On reaching the ground his feet come to rest but upper part of the body continues to move with the speed of vehicle and the person falls forward on the ground. It is dangerous to jump out of a moving train and it is better to come out when it halts. However if in case of some emergency if some person wants to jump safely from a moving vehicle he should run for quite a while in the direction of motion of the vehicle after the jump so that his entire body remains in motion for sometime.

(ii) When a running car stops suddenly, the passenger is jerked forward. The reason is that in a running car, the whole body of passenger is in the state of motion. As the car stops suddenly, the lower part of his body being in contact with the car, comes to rest but his upper part remains in the state of motion due to the inertia of motion. Thus he gets jerked forward.

(iii) In an event of long jump, an athlete runs fast before making the jump. Due to inertia of motion he is able to jump to a longer distance.

(iv) When we shake a wet piece of cloth, cloth as well as water in it comes to motion but when cloth comes to rest, the water is still moving due to the inertia of motion and falls forward on the front body of the person.

3. **Inertia of direction :** It is the inability of a body to change by itself, its direction of motion.

Example:

(i) When a straight running car turns sharply, the person sitting inside feels a force radially outwards.

(ii) Rotating wheels of vehicle throw out mud, on the inner side of mudguard over the wheels.

(iii) A body released from a balloon rising up, continues to move in the direction of balloon.

CHECK POINT-1

1. A man getting down a running bus falls forward
   (a) due to inertia of rest, road is left behind and man reaches forward
   (b) due to inertia of motion upper part of body continues to be in motion in forward direction while feet come to rest as soon as they touch the road
   (c) as he leans forward as a matter of habit
   (d) due to the combined effect of all the three factors stated in (a), (b) and (c)
2. Newton's first law of motion is also called
   (a) law of inertia (b) law of gravitation
   (c) law of action/reaction (d) law of force and acceleration
3. An unbalanced force acts on a body. Then the body:
   (a) must remain at rest (b) must move with uniform velocity
   (c) must be accelerated (d) must move along a circle
4. On the basis of following features identify the correct option.
   A. It is measured in units of kg m/s.
   B. Its direction is same as that of velocity of body.
   (a) Momentum (b) Inertia
   (c) Both A and B (d) Neither A and B

Solutions:

1. **(b)** 2. **(a)**
3. **(c)** must be accelerated
4. **(a)** Momentum p = mv. Its unit is kg-m/s

SECOND LAW OF MOTION

Most of us know from our experience of playing cricket that a cricket ball moving with a high speed could be fatal. Is it due to the velocity of the ball only ? Had it been so, a dust particle moving with the same velocity would have been equally fatal. On the other hand, it could not be only due to the mass of the ball as we can safely hold a stationary (or a slowly moving) cricket ball in our hand without any fear. From this and many such examples we conclude that a quantity consisting the product of mass and velocity (mv) is of much significance. This quantity is so important in physics that it is given its own name and symbol. We call this quantity as momentum and represent it by symbol p.

Momentum is a measure of the quantity of motion in a body.

Example : Consider, a truck and a rickshaw moving with same velocities, heading towards each other and eventually ending up in a head on collision. Needless to say, that the rickshaw might get deformed to such an extent, that it would be difficult for us to make it, were it was a rickshaw before ! However, the truck might get some minor damages. Why is it so ? The first thing that comes to mind, is because the truck has more mass. Exactly! But in this context, it is more wise to say that , it all happens because the truck has more quantity of motion (i.e., momentum).

The momentum of a moving body is defined as the product of its mass and velocity. If we represent the mass and velocity of a body by m and $\vec{v}$ respectively, then momentum is given by

$$\vec{p} = m\,\vec{v}$$

The direction of momentum of a body is same as that of its velocity. If only the magnitude is considered, then

$$p = mv$$

The **SI unit** of momentum is kilogram meter per second (kgm/s).

Illustration 3 :

A ball of mass 500g is thrown with a velocity of 72 km/h. What is its initial momentum ?

Solution :

Given mass of the ball = 500g = $\frac{1}{2}$kg and velocity (initial) of the ball = 72 km/h = 20 m/s

$\therefore$ Momentum of the ball $p = mv = \frac{1}{2} \times 20 = 10 \text{ kg m/s}$

Mathematical Formulation of Second Law of Motion

The rate of change of momentum of a body is directly proportional to the applied unbalanced force.

i.e., Rate of change of momentum $\propto$ force applied

or, $F \propto \frac{\Delta p}{\Delta t}$

If a body is moving with initial velocity u and after applying a force F on it. Its velocity becomes v in time t, then

Initial momentum of the body $p_1 = mu$

Final momentum of body $p_2 = mv$

Change in momentum in time $t = mv - mu$

So, rate of change of momentum = $\frac{mv - mu}{t}$

But according to Newton's second law, $\frac{mv - mu}{t} \propto F$ or $F \propto \frac{m(v-u)}{t}$

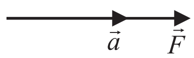
Here $\frac{v-u}{t} = a$ (acceleration)

So $F \propto$ ma or $F = k\,ma$, where k is proportionality constant.

If 1N force is applied on a body of mass 1 kg and the acceleration produced in the body is 1 m/sec² then $1 = k \times 1 \times 1$ or $k = 1$

Hence, $\boldsymbol{F = ma}$

So, the magnitude of the resultant force acting on a body is equal to the product of mass of the body and the acceleration produced. Direction of the force is same as that of the acceleration.



The Logical Connection between Newton's First and Second Laws

Newton's first law asserts that a body tends to move with constant velocity. Newton's second law provides a quantitative measure of the force that will produce a given acceleration of the mass.
At first glance, it may seem that the Newton's first law is not an independent law of nature at all, but merely the special case of Newton's second law, $F = ma$, in which the net external force is zero. If $F = 0$, we have $a = F/m = 0$ and therefore v = constant, as the first law states. Is this all there is to Newton's first law ? No, because this interpretation of Newton's first law is based on an incomplete statement of the law.

Impulse

From Newton's second law, $\vec{F} = \frac{\Delta\vec{p}}{\Delta t}$, we can derive the **impulse-momentum theorem**. This theorem states that impulse is equal to the change in momentum, or $\vec{F}\Delta t = \Delta\vec{p} = \vec{p} - \vec{p}_0$ where $\vec{F}\Delta t$ is called impulse, $\vec{F}$ is the average force and Δt is the time interval the force is in action).

Since impulse is product of force and time, it is measured in either newton-s or $kgms^{-1}$ the unit of momentum. Impulse-momentum is very useful in explaining some everyday phenomena like a cricket player while taking a catch always moves his hands backward, because the total change in momentum $(mv - mu)$ remains constant for a moving ball. The change in momentum is numerically equal to $F \times t$. Here F is force applied by the hands for time t. Now the player moves his hands backward so that the value of t will increase. With the result the value of applied force F will decrease.

Thus the hands of the player are not hurt while taking a catch. Similarly the idea of the impulse of a force is important when considering a hammer driving a nail into a block of wood, a boy kicking a football and a girl striking a hockey ball.

DID YOU KNOW?

The change in momentum of a body depends on the magnitude and direction of the applied force and the period of time over which it is applied; i.e. it depends on its impulse.

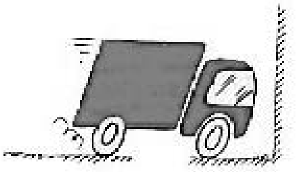
Examples :

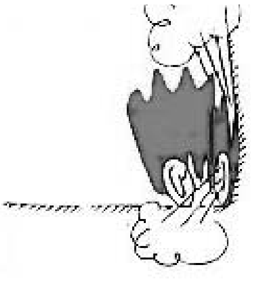
(i) A girl standing at rest with her right foot on a skateboard thrusts backwards on the ground with her left foot. The push of the ground on her left foot will increase the forward momentum of the girl and skateboard.

From $Ft = mv - 0$, the velocity v acquired by the girl will depend on the force F which can be applied and the time t for which it acts.

(ii) A body throwing a javelin is shown in figure. For a javelin of a given mass, the distance it will travel depends upon the force exerted by the boy's arm and the time for which it is exerted.

(iii) During the collision of a truck with the wall, wall exerts great impulse on truck





CASE STUDY-2 : Understand Inertia, Force and Momentum

Inertia is the inability of a body to change by itself, its state of rest or state of uniform motion or its direction of motion.

Greater the inertia, greater the mass, greater the force required to bring a change in its state of rest or of uniform motion.

Mass is a measure of the inertia of a body.

If two bodies of same mass moving with different speeds then greater force is required to stop the body moving with higher speeds.

So, quantity of motion depends on the mass and velocity of the body. The product of mass and velocity is called momentum.

Momentum, P = m × v

If force $\vec{F}$ is applied on a body then

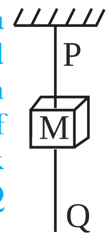
$$F \propto \frac{\text{Change in momentum}}{\text{time taken}} = K\left(\frac{mv - mu}{t}\right) = Km\left(\frac{v-u}{t}\right)$$

$\because \left(\frac{v-u}{t}\right) = a$ and K is a constant and its value in S.I. unit = 1

$\therefore$ $F = m \times a$

CASE - I: The change in momentum of a body depends on the magnitude and direction of the applied force and the period of time over which it is applied.

CASE - II: If a mass M is suspended by a string P and another string Q is connected to lower end (see figure) and if a sudden jerk is given to Q then the portion MQ of the string will break as due to sudden jerk before reaching string A, the tension in MQ portion increases the breaking tension.



CASE-III: In the arrangement shown in case II, if the string Q is stretched slowly, then the portion PM of the string will break as in this case due to weight and transfer to tension to the portion PM, it breaks first.

Think Out of the Box

Q 1. A table cloth can be pulled from a table without dislodging the dishes.
[**Hint:** Inertia]
[**Ans.** When cloth is pulled from a table, the cloth comes in state of motion but dishes remain stationary due to inertia]

Q 2. How a Karate player can break a pile of tiles with a single blow of his hand?
[**Hint:** In very short interval of time the entire momentum of the hand reduced to zero, so very large force is delivered.]

Q 3. Why these days all the cars are provided with seat belts for passangers?
[**Hint:** The stretchable seat belts worn by the passangers increase the time interval.]

Illustration 4 :

A body of mass 5 kg at rest is acted upon by a force. Its velocity changes to 5 ms^{-1}. Find its initial and final momentum.

Solution :

Given Mass, $m = 5$ kg

Initial velocity, $u = 0\ ms^{-1}$

Final velocity, $v = 5\ ms^{-1}$

Initial momentum (p_1)

Since the body is at rest, its initial momentum is zero

($\because P$ = mass × velocity)

$p_1 = 0$

Final momentum (p_2)

$p_2 = mv$

$p_2 = (5\ kg) \times (5\ ms^{-1}) = 25\ kg\ ms^{-1}$

Illustration 5 :

A motorcar is moving with a velocity of 108 km/h and it takes 4s to stop after the brakes are applied. Calculate the force exerted by the brakes on the motorcar if its mass along with the passengers is 1000 kg.

Solution :

The initial velocity of the motorcar

$u = 108\ km/h = 108 \times 1000\ m/(60 \times 60s) = 30\ ms^{-1}$

and the final velocity of the motorcar $v = 0\ ms^{-1}$

The total mass of the motorcar along with its passengers = 1000 kg and the time taken to stop the motorcar, $t = 4s$.

We have the magnitude of the force (F) applied by the brakes as $\frac{m(v-u)}{t}$

On substituting the values, we get

$F = 1000\ kg \times (0 - 30)\ ms^{-1}/4s = -7500\ kg\ ms^{-2}$ or -7500 N

The negative sign tells us that the force exerted by the brakes is opposite to the direction of motion of the motorcar.

Illustration 6 :

A force of 20N acts on a body of mass 5 kg for 5 sec. Find:

(i) the acceleration of the body

(ii) velocity at the end of 5 sec, and

(iii) displacement at the end of 5 sec.

Solution :

Given : $F = 20$ N, $m = 5$ kg and $t = 5$ sec.

(i) From $\vec{F} = m\vec{a} \Rightarrow 20 = 5 \times a$

Thus, acceleration $a\ \frac{20}{5} = 4\ m/s^2$

(ii) $u = 0,\ a = 4,\ t = 5,\ v = ?$

Using $v = u + at$

$v = 0 + 5 \times 4 = 20$ m/s

(iii) $u = 0,\ a = 4,\ t = 5,\ s = ?$

From $s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2} \times 4 \times 25 = 50m$

Illustration 7 :

A ball of mass 10g is initially moving with a velocity of 50 ms^{-1}. On applying a constant force on ball for 2.0 s, it acquires a velocity of 70 ms^{-1}. Calculate :

(i) the initial momentum of ball
(ii) the final momentum of ball
(iii) the rate of change of momentum
(iv) the acceleration of ball, and
(v) the magnitude of force applied

Solution :

Given : $m = 10\text{g} = \frac{10}{1000}\text{kg} = 0.01\text{ kg}$

$u = 50\text{ ms}^{-1}$, $t = 2.0\text{s}$, $v = 70\text{ ms}^{-1}$.

(i) Initial momentum of ball = mass × initial velocity = mu = 0.01 kg × 50 ms^{-1} = 0.5 kg ms^{-1}.

(ii) Final momentum of the ball = mass × final velocity = mv = 0.01 kg × 70 ms^{-1} = 0.7 kg ms^{-1}.

(iii) Rate of change of momentum = $\frac{\text{final momentum} - \text{initial momentum}}{\text{time interval}} = \frac{(0.7 - 0.5)\text{ kg ms}^{-1}}{2.0\text{s}} = 0.1\text{ kg ms}^{-2}$ (or 0.1 N)

(iv) Acceleration $a = \frac{v-u}{t} = \frac{70-50}{2} = 10\text{ ms}^{-2}$

(v) Force = mass × acceleration = ma = 0.01 kg × 10 ms^{-2} = 0.1N

Illustration 8 :

A 650-kilogram rocket is to be speeded up from 440 meters per second to 520 meters per second in outer space. If the thrust of the engine is 1200 newtons, for how long must the engine be fired ?

Solution :

The change in the momentum of the rocket ΔP = mv – mu

= (650) (520) – (650) (440) = 52000 kg m/s.

This must be equal to the impulse, so F Δt = (1200 *N*) (Δ*t*) = 52000 kg m/s

∴ Δ*t* = 43*s*

CHECK POINT-2

1. A body whose momentum is constant must have constan
(a) velocity (b) force (c) acceleration (d) All of these

2. The force required to stop a car of mass 800 kg, moving at a speed of 20 ms–1 over a distance of 25 m in 2.5 sec is
(a) 1200 N (b) 6400 N (c) 1600 N (d) 1800 N

3. A force produces an acceleration of 2.0 m/s^2 in a body ‘A’ and 5.0 m/s^2 in another body ‘B’. The ratio of the mass of ‘A’ to the mass of ‘B’ is :
(a) 2.5 (b) 3.5 (c) 5.5 (d) 4.5

4. A force produces an acceleration of 0.5 m/s^2 n a body of mass 3.0 kg. If the same force acts on a body of mass 1.5 kg the acceleration produced in it is
(a) 3.0 m/s^2 (b) 1.0 m/s^2 (c) 5.0 m/s^2 (d) 7 m/s^2

Solutions:

1. (a) It works on the principle of conservation of linear momentum.

2. (b) As we know, $|a| = \left|\frac{v^2 - u^2}{2S}\right| = \frac{400}{50} = 8\text{ m/s}^2$. So force required = F = ma = 800 × 8 = 6400 N

3. (a) F = constant ⇒ ma = const.

⇒ $\frac{m_A}{m_B} = \frac{a_B}{a_A} = \frac{}{2} = 2.5$

4. (b) Force is constant.
But F = ma = constant.
⇒ $m_1a_2 = m_2a_2 \Rightarrow 3 \times 0.5 = 1.5\ a_2 \Rightarrow a_2 = 1\text{ m/s}^2$

THIRD LAW OF MOTION

Newton's first two laws of motion describe what happens to a single object that has forces acting on it while Newton's third law deals with the relationship between the forces objects exert on each other.

If we push on a wall it pushes back. This doesn't hurt if you push gently, but if you punch a wall hard it hurts very much . Newton hypothesized that any time two objects interact in such a way that a force is exerted on one of them, there is always a force that is equal in magnitude exerted in the opposite direction on the other object. This hypothesis is called Newton's third law.

i.e., *To every action there is always an equal and opposite reaction.*

Newton's third law of motion states that 'if a body *A* exerts a force $+F$ on a body *B*, then body *B* exerts a force $-F$ on *A*, that is a force of the same size and along the same line of interaction but in the opposite direction'. This law says that forces always occur in pairs as the result of the interaction between two objects. Note that two objects are involved and the two forces each act on a different object. The two opposing forces are sometimes called the action and reaction forces.

DID YOU KNOW?

The paired forces (called action and reaction) always act on different bodies. There is no way one of them can balance the other one!

Examples:

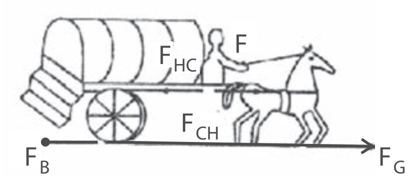
(i) Motor cars are able to move along a road because the reaction of the road pushes the car along in response to the action of the wheels pushing on the road.

(ii) A swimmer pushes (or applies force) the water with his hands and feet to move in the forward direction in water. It is the reaction to this force that pushes the swimmer forward.

(iii) The propellers of an aeroplane pushes the air backwards and the forward reaction of the air makes the aeroplane move forward.

(iv) When a bullet is fired from a gun, the force sending the bullet forward is equal to the force sending the gun backward. But due to the high mass of the gun, it moves only a little distance backward and gives a kick to the shoulder of the gunman. The gun is said to have recoiled.

(v) Consider, a horse cart being driven by a horse. The horse pulls forward, the cart with a force F_{CH}. The cart also pulls the horse with an equal force F_{HC}, but in opposite direction. But then how does the complete system (horse + cart) moves forward ? The reason is that there are yet some other forces active on the system, which lead to the movement of the horse-cart system.



The forward thrust, F_G offered by the frictional force between ground and horse and the frictional force acting backwards, between ground and cart F_B.

Thus, the net force on the system, acting forwards is given by

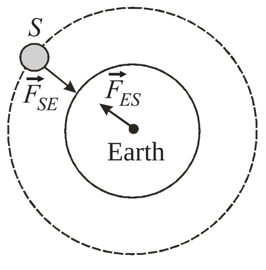
$$F = F_G - F_{HC} + F_{CH} - F_B$$

$$F = F_G - F_B \qquad [\because F_{HC} = F_{CH}]$$

Now, if $F_G > F_B$, then $F > 0$

and hence the system would start moving with an acceleration $a = \frac{F}{m} = \frac{F_G - F_B}{m}$ where *m* is the mass of the system.

But if $F_G < F_B$, no motion is possible.

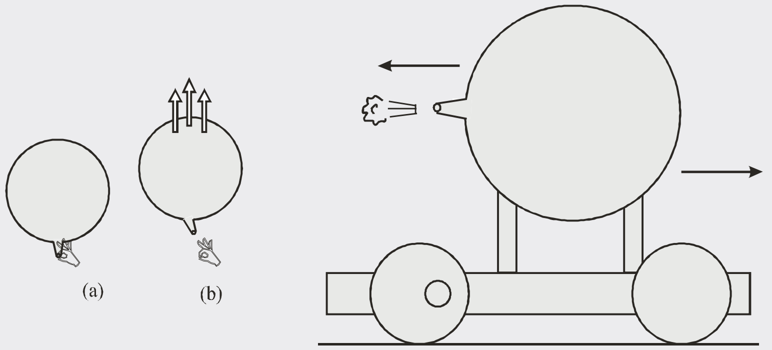


(vi) For an orbiting satellite action of earth on the satellite is the force exerted on the satellite by the gravitational pull of the earth $(\vec{F}_{SE})$

Reaction of the satellite on the earth. It is the gravitational pull of the satellite on the earth $(\vec{F}_{ES})$.

Let's Do Activity

Aim : *To study Newton's III*rd *law of motion – For every action there is equal and opposite reaction.*
Requirement : *Toy car, balloon, ballpoint refill etc.*
Procedure : *Tie the mouth of a balloon tightly to a small piece of discarded ballpoint refill or a plastic tube having a narrow bore and inflate it. Close the opening of the tube with your finger to prevent the air to escape (fig. (a)). Now let the air escape from the opening of the tube (fig. (b)). In doing this activity you may also fix the inflated balloon on the top of a toy car or a trolley before you let the air escape (fig. c).*



(a) (b) (c)

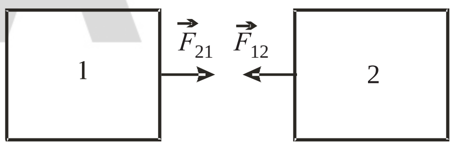
Observation : *The toy car moves in the direction opposite to the direction in which the air escapes. This is the basic principle involved in the working of jet engines and rockets. In jet engines, a large volume of gases produced by the combustion of fuel is allowed to escape through a jet and as a result, it moves the forward.*
Conclusion : *We study Newton's III*rd *law of motion.*

Newton's Third Law from Newton's Second Law

Let us consider two bodies 1 and 2. Let F_{21} be the force exerted by second body on first and F_{12} the force exerted by the first body on second.

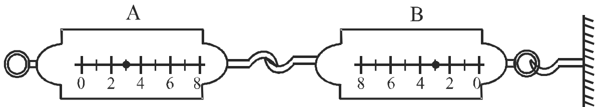
External force = 0, $m \times a = 0 \Rightarrow \frac{m(\Delta v)}{\Delta t} = 0$

$\therefore \quad \vec{F}_{21} + \vec{F}_{12} = 0 \quad \Rightarrow \vec{F}_{21} = -\vec{F}_{12}$



Experiment: Demonstrating action and reaction

The ring of a spring balance *B* is attached to the hook fixed in a wall and then the hook of another spring balance *A* is attached to the hook of the spring balance *B*. Now the ring of balance *A* is pulled. We find that both the balances represent the same reading. The reason is that the balance *A* pulls the balance *B* due to which we get some reading in *B*. But the same reading in balance *A* shows that the balance *B* also pulls the balance *A* by the same force of reaction. This concludes that "to every action, there is an equal and opposite reaction" (i.e., $F_{AB} = F_{BA}$ but in opposite direction).



Reading = 3kg f   Reading = 3kg f

Illustration 9 :

Do action and reaction act on the same body? How are they related in magnitude and direction?
Solution :
No, action and reaction always act on different bodies. They are equal in magnitude and opposite in direction.

Illustration 10 :

If a boy jumps out from a boat, the boat moves forwards. Yes/No. Why?
Solution :
No, the boat moves backwards. As the boy moves forward so as per Newton's third law of motion as a reaction boat moves backwards.

CONNECTING TOPIC

Conservation of Momentum

If no external force acts on a system (called isolated) of constant mass the total momentum of the system remains constant (with time).

If the total external force acting on a system is equal to zero, then the final value of the total momentum of the system is equal to the initial value of the total momentum of the system.

$\vec{F}_{ext} = \frac{d\vec{p}}{dt}$ If $\vec{F}_{ext} = 0$, i.e., $\frac{d\vec{p}}{dt} = 0$ then

$\vec{p}$ = constan or $\vec{p}_f = \vec{p}_i$

Examples of conservation of linear momentum

(1) Bomb shell explosion **(2) Recoil of the gun** **(3) Jet engines and Rockets**

Let's Connect

1. Law of conservation of momentum follows from

(a) Newton's first law of motion (b) Newton's second law of motion

(c) Newton's third law of motion (d) Both (b) & (c)

2. A bomb of mass 16 kg explodes into two pieces of masses 4 kg and 12 kg. The velocity of the 12 kg mass is 4 ms^{-1}. The kinetic energy of the second piece is

(a) 144 J (b) 192 J (c) 96 J (d) 288 J

Solutions:

1. (d)

2. (d) Using conservation of linear momentum,

$m_1v_1 = m_2 v_2 \Rightarrow 12 \times 4 = (16 - 12) \times v_2 \Rightarrow v_2 = 12$ m/s

$\therefore$ Kinetic energy of second piece $KE_2 = \frac{1}{2} m_2v_2^2 = \frac{1}{2} \times 4 \times (12)^2 = 288$ J

CHECK POINT-3

1. According to the third law of motion, action and reaction

(a) always act on the same body

(b) always act on different bodies in opposite directions

(c) have same magnitude and directions

(d) act on either body at normal to each other

2. When a horse pulls a cart, the force that helps the cart to move forward is the force exerted by:

(a) the cart on the horse (b) the ground on the horse

(c) the ground on the cart (d) the horse on the ground

3. Swimming is possible on account of

(a) first law of motion (b) second law of motion

(c) third law of motion (d) Newton's law of gravitation

4. A man drawing a bucket of water falls back when the rope snaps. This is because of

(a) law of gravitation (b) 1st law of motion

(c) Newton's 11 law of motion (d) Newton's III law of motion

Solutions:

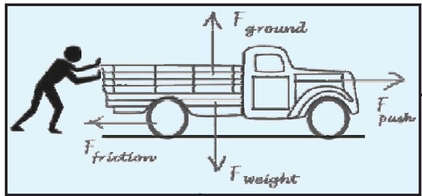
1. (b) Always act on different bodies in opposite directions.

2. (b) The horse presses the ground with a force in an inclined direction, the reaction of the ground acts on the horse in opposite direction.

3. (c) While swimming, a person pushes water with his hands in backward direction (action) and water pushes him forward (reaction).

4. (d) Action and reaction act on two different bodies on the bucket and the man in opposite direction.

Walk Through the Chapter



Force is a push or pull acting on a body. Changes state of rest or motion and direction.

Units of Force

The **S.I. unit** of force is newton.

One newton is the force which when acts on a body of mass 1 kg, produces an acceleration of 1 ms^{-2}.

i.e., 1 newton (N) = 1 kg × 1 ms^{-2}

Unbalanced force

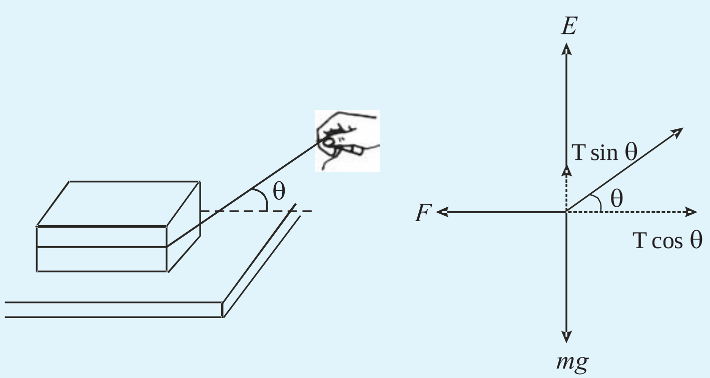
A set of forces acting on a body produces non-zero acceleration in it.

Balanced force

A set of forces acting on a body produces no acceleration in it.

Equilibrium of forces

The situation when net external force on the particle is zero.



Newton's 1st Law of Motion

The tendency of undisturbed objects to stay at rest or to keep moving with the same velocity.

Inertia

Resistance to change

Types of inertia

(i) inertia of rest

(ii) inertia of motion

(iii) inertia of direction

Newton's 2nd Law of Motion

Unbalanced force on a body causes acceleration

$$F = m \times a = m \times \left(\frac{v-u}{t}\right)$$

Impulse

P(momentum) = mv

Δ momentum = F.Δt

= Impulse

Momentum (P)

Product of mass (m) and velocity (v) of the body,

$\vec{P} = m\vec{v}$

Newton's 3rd Law of Motion

Every action has equal and opposite reactions.

$F_A = -F_B$

The paired forces (called action and reaction) always act on different bodies. There is no way one of them can balance the other one!

Let's Revise Through FIB & T/F

1. The SI unit of force is the ....
2. When a running car stops suddenly, the passengers are jerked ....
3. .... is a measure of the inertia of a body.
4. More the mass of a body, more its inertia. (T/F)
5. If particle is initially at rest then it moves in direction of net force. (T/F)
6. No net force acts on a rain drop falling vertically with a constant speed. (T/F)
7. If there are several forces on an object, its acceleration depends on its mass and the .... force.
8. It is easier to start motion in a lighter body than a heavier body. (T/F)
9. Particle is at rest, if force is zero. (T/F)
10. If net force acting on the body is zero, momentum of the body remains constant. (T/F)
11. Momentum is never created nor destroyed (T/F)
12. The product of the mass of a body and its velocity is called inertia. (T/F)
13. The change in the velocity of an object is proportional to the ....applied to it.
14. The change in the momentum of an object is equal to the .... applied to it.
15. ....is equal to change in momentum.
16. First law of motion is called law of inertia. (T/F)
17. Force is equal to mass × acceleration. (T/F)
18. To every action, there is an............. and.................. reaction ....
19. When we push our foot against the ground backwards (action), the ground exerts an equal and opposite force (reaction) on our foot which causes us to move forward. (T/F)
20. Action and reaction force acts on the same object (T/F)

EXERCISE-1 Master Board

Multiple Choice Questions

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which only one is correct.*

1. Inertia is that property of a body by virtue of which the body is
   (a) unable to change by itself the state of rest
   (b) unable to change by itself the state of uniform motion
   (c) unable to change by itself the direction of motion
   (d) All of the above
2. An object will continue moving uniformly when
   (a) the resultant force on it is increasing continuously
   (b) the resultant force is at right angles to its rotation
   (c) the resultant force on it is zero
   (d) the resultant force on it begins to decrease
3. We can derive Newton's
   (a) second and third laws from the first law
   (b) first and second laws from the third law
   (c) third and first laws from the second law
   (d) All the three laws are independent of each other
4. When a body is stationary
   (a) there is no force acting on it
   (b) the force acting on it is not in contact with it
   (c) the combination of forces acting on it balances each other
   (d) the body is in vacuum
5. Newton's second law measures the
   (a) acceleration (b) force
   (c) momentum (d) angular momentum
6. A rider on a horse back falls forward when the horse suddenly stops. This is due to
   (a) inertia of horse
   (b) inertia of rider
   (c) large weight of the horse
   (d) losing of the balance
7. A man is at rest in the middle of a pond of perfectly smooth ice. He can get himself to the shore by making use of Newton's
   (a) first law (b) second law
   (c) third law (d) All of the above
8. A cannon after firing recoils due to
   (a) conservation of energy
   (b) backward thrust of gases produced
   (c) Newton's third law of motion
   (d) Newton's first law of motion
9. A jet plane moves up in air because
   (a) the gravity does not act on bodies moving with high speeds

(b) the thrust of the jet compensates for the force of gravity
(c) the flow of air around the wings causes an upward force, which compensates for the force of gravity
(d) the weight of air whose volume is equal to the volume of the plane is more than the weight of the plane

10. The force required to stop a car of mass 800 kg, moving at a speed of 20 ms^{-1} over a distance of 25 m in 2.5 sec is
(a) 1200 N (b) 6400 N
(c) 1600 N (d) 1800 N

11. The force of action and reaction
(a) must be of same nature
(b) must be of different nature
(c) may be of different nature
(d) may not have equal magnitude

12. The direction of impulse is
(a) same as that of the net force
(b) opposite to that of the net force
(c) same as that of the final velocity
(d) same as that of the initial velocity

13. A force F_1 acting on a body of 2 kg produces an acceleration of 2.5 m/sec². An other force F_2 acting on the another body of mass 5 kg produces an acceleration of 2 m/sec². Find the ratio of F_1/F_2.
(a) 2 : 1 (b) 4 : 1 (c) 1 : 2 (d) 1 : 8

14. The velocity of a mass of 20 kg decreases from 20 m/s to 5 m/s in travelling a distance of 100 m. The force acting on the body is
(a) – 27.5 N (b) – 37.5 N
(c) – 47.5 N (d) – 67.5 N

15. If a boat is moving along a constant speed, it may be assumed that
(a) a net force is pushing it forward
(b) the sum of only vertical forces is zero
(c) the buoyant force is greater than gravity
(d) the sum of all forces is zero

16. What force is needed to a accelerate a 60-kilogram wagon from rest to 5.0 meters per second in 2.0 seconds
(a) 100 N (b) 120 N (c) 150 N (d) 130 N

17. A frictionless wagon going at 2.5 meters per second is pushed with a force of 380 N, and its speed increases to 6.2 meters per second in 4.0 seconds. What is its mass –
(a) 410 kg (b) 420 kg (c) 480 kg (d) 310 kg

18. What braking force is needed to bring a 2200 kilogram car going 18 meters per second to rest in 6.0 seconds ?
(a) 6600 N (b) 6500 N (c) 6000 N (d) 6200 N

19. What force is needed to speed up a frictionless 60 kg cart from 4.0 meters per second to 6.5 meters per second in 3.0 seconds ?
(a) 50 N (b) 100 N (c) 5N (d) 20 N

20. The inertia of a body depends upon
(a) Gravitational acceleration
(b) Centre of gravity of body
(c) Shape of body
(d) Mass of body

Assertion & Reason Questions

DIRECTIONS : *The questions in this segment consists of two statements, one labelled as "Assertion A" and the other labelled as "Reason R". You are to examine these two statements carefully and decide if the Assertion A and Reason R are individually true and if so, whether the reason is a correct explanation of the assertion. Select your answers to these items using the codes given below.*
(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

1. **Assertion (A):** Mass is a measure of inertia of the body.
Reason (R): Greater the mass, greater is the force required to change its state of rest or of uniform motion.

2. **Assertion (A):** If the net external force on the body is zero, then its acceleration is zero.
Reason (R): Acceleration does not depend on force.

3. **Assertion (A):** A cricketer moves his hands backward to catch a ball so as to catch it easily without hurting.
Reason (R): He tries to decrease the distance travelled by the ball so that it hurts less.

4. **Assertion (A):** The wings of a bird push air upwards and the air must be pushing the bird downwards.
Reason (R): For every action there is an equal and opposite reaction.

5. **Assertion (A):** Force exerted by the ground on the man moves him forward.
Reason (R): It is a reactional force.

Multiple Matching Questions

DIRECTIONS : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r and s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in column I with entries in column II.*

1.

Column I	Column II
(A) To every action there is equal and opposite	(p) Force
(B) Rate of change of velocity is	(q) Reaction
(C) Rate of change of momentum is	(r) Acceleration
(D) Force that opposes motion	(s) Force of Friction

2. **Column I** — **Column II**

Column I	Column II
(A) Force	(p) kg ms^{-1}
(B) Momentum	(q) newton
(C) Mass	(r) kg
(D) Acceleration	(s) ms^{-2}

Passage/Case Based Question

DIRECTIONS : *Read the passage (s) given below and answer the questions that follow.*

1. According to Newton's Third law, whenever an object exerts a force on another object, the latter object exerts an equal and opposite force on the first. We can call one force the action force, and the other the reaction force. In action-reaction form, the third law is stated as *to every action there is always an equal and opposite reaction*.
   (i) The force of action and reaction acts on
   (a) same body (b) different body
   (c) lower body (d) upper body
   (ii) Recoiling of a cannon after firing a shot is an example of
   (a) Newton's first law
   (b) Newton's second law
   (c) Newton's third law
   (d) Newton's law of Gravitation

Very Short Answer Questions

DIRECTIONS : *Give answer in one word or one sentence.*

1. The two ends of a spring-balance are pulled each by a force of 10 kg-wt. What will be the reading of the balance?
2. Under what circumstances is Newton's first law same as Newton's second law.
3. Write the equation of Newton's second law when the body is moving opposite to the direction in which force is applied.
4. What can happen if passangers do not wear seat belts while travelling in a car? **[Reasoning Based]**
5. It is the balanced force that can produce motion in a stationary object but cannot change the shape of the object. Yes/No. Give reason. **[Reasoning Based]**
6. Why an athlete is advised to come to stop slowly after finishing a fast race? **[Reasoning Based]**
7. Why in a tug of war, if one of the teams suddenly releases the rope, the other team falls backwards? **[Reasoning Based]**

Short Answer Questions

DIRECTIONS : *Give answer in 2-3 sentences.*

1. What is inertia ? Why do we call the Newton's first law as the law of inertia ? Explain.
2. Show that the Newton's first law of motion gives the qualitative definition of force and the second law gives the measure (or quantitative definition) of force.
3. State Newton's second law of motion. Show that it gives the measure of force.
4. What is force ? What are its absolute and gravitational units ? How are these related to each other?
5. Define the terms momentum and impulse. Obtain the relation between impulse and momentum.
6. If an inflatted balloon is released with its mouth in the downward direction then it will move upwards. Yes/No. Why? **[Reasoning Based]**
7. According to Newton's 3rd law of motion, action is always equal to reaction, then why a cart pulled by a horse can be moved? **[Reasoning Based]**

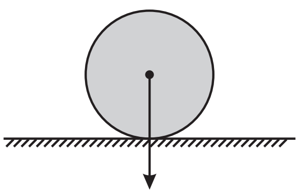
Long Answer Questions

DIRECTIONS : *Give answer in 4-5 sentences.*

1. Water skier is towed by a motorboat at a constant velocity of magnitude 15 km/h. The boat speeds up, and after a short interval the skier is towed at a new constant velocity of magnitude 20 km/h. What is the net force on the skier when she is moving at 15 km/h and at 20 km/h?
2. State Newton's second law of motion. Hence, derive the equation of motion $F = m.a$. From it obtain the unit of force in SI. Show that Newton's second law of motion is the real law of motion.
3. State Newton's laws of motion.

HOTS Questions

1. When your hand turns the handle of a faucet, water comes out. Do your push on the handle and the water coming out comprise an action-reaction pair ? Defend your answer.
2. A stone is shown at rest on the ground.
   (a) The vector shows the weight of the stone. Complete the vector diagram showing another vector that results in zero net force on the stone.
   (b) What is the conventional name of the vector you have drawn ?



EXERCISE-2 NCERT Questions

In-text Book Questions

1. Which of the following has more inertia :
   (a) a rubber ball and a stone of the same size?
   (b) a bicycle and a train?
   (c) a five-rupees coin and a one-rupee coin?
2. Explain why some of the leaves may get detached from a tree if we vigorously shake its branch.
3. Why do you fall in the forward direction when a moving bus brakes to a stop and fall backwards when it accelerates from rest?
4. If action is always equal to the reaction, explain how a horse can pull a cart.
5. Explain, why it is difficult for a fireman to hold a hose, which ejects large amounts of water at a high velocity.
6. From a rifle of mass 4 kg, a bullet of mass 50 g is fired with an initial velocity of 35 m s^{-1}. Calculate the initial recoil velocity of the rifle.
7. Two objects of masses 100 g and 200 g are moving along the same line and direction with velocities of 2 m s^{-1} and 1 m s^{-1}, respectively. They collide and after the collision, the first object moves at a velocity of 1.67 m s^{-1}. Determine the velocity of the second object.

Text-Book Exercise

1. An object experiences a net zero external unbalanced force. Is it possible for the object to be travelling with a non-zero velocity? If yes, state the conditions that must be placed on the magnitude and direction of the velocity. If no, provide a reason.
2. When a carpet is beaten with a stick, dust comes out . Explain why ?
3. Why is it advised to tie any luggage kept on the roof of a bus with a rope?
4. A batsman hits a cricket ball which then rolls on a level ground. After covering a short distance, the ball comes to rest. The ball slows to a stop because
   (a) the batsman did not hit the ball hard enough.
   (b) velocity is proportional to the force exerted on the ball.
   (c) there is a force on the ball opposing the motion.
   (d) there is no unbalanced force on the ball, so the ball would want to come to rest.
5. A truck starts from rest and rolls down a hill with a constant acceleration. It travels a distance of 400 m in 20 s. Find its acceleration. Find the force acting on it if its mass is 7 metric tonnes (Hint: 1 metric tonne = 1000 kg.)
6. A stone of 1 kg is thrown with a velocity of 20 m s^{-1} across the frozen surface of a lake and comes to rest after travelling a distance of 50 m. What is the force of friction between the stone and the ice?
7. A 8000 kg engine pulls a train of 5 wagons, each of 2000 kg, along a horizontal track. If the engine exerts a force of 40000 N and the track offers a friction force of 5000 N, then calculate:
   (a) the net accelerating force;
   (b) the acceleration of the train;
8. An automobile vehicle has a mass of 1500 kg. What must be the force between the vehicle and road if the vehicle is to be stopped with a negative acceleration of 1.7 m s^{-2}?
9. What is the momentum of an object of mass m, moving with a velocity v?
   (a) $(mv)^2$ (b) mv^2
   (c) $\frac{1}{2} mv^2$ (d) mv
10. Using a horizontal force of 200 N, we intend to move a wooden cabinet across a floor at a constant velocity. What is the friction force that will be exerted on the cabinet?
11. Two objects, each of mass 1.5 kg, are moving in the same straight line but in opposite directions. The velocity of each object is 2.5 m s^{-1} before the collision during which they stick together. What will be the velocity of the combined object after collision?
12. According to the third law of motion when we push on an object, the object pushes back on us with an equal and opposite force. If the object is a massive truck parked along the roadside, it will probably not move. A student justifies this by answering that the two opposite and equal forces cancel each other. Comment on this logic and explain why the truck does not move.
13. A hockey ball of mass 200 g travelling at 10 m s^{-1} is struck by a hockey stick so as to return it along its original path with a velocity at 5 m s^{-1}. Calculate the change of momentum occurred in the motion of the hockey ball by the force applied by the hockey stick.
14. A bullet of mass 10 g travelling horizontally with a velocity of 150 m s^{-1} strikes a stationary wooden block and comes to rest in 0.03 s. Calculate the distance of penetration of the bullet into the block. Also calculate the magnitude of the force exerted by the wooden block on the bullet.
15. An object of mass 1 kg travelling in a straight line with a velocity of 10 m s^{-1} collides with, and sticks to, a stationary wooden block of mass 5 kg. Then they both move off together in the same straight line. Calculate the total momentum just before the impact and just after the impact. Also, calculate the velocity of the combined object.
16. An object of mass 100 kg is accelerated uniformly from a velocity of 5 m s^{-1} to 8 m s^{-1} in 6 s. Calculate the initial and final momentum of the object. Also, find the magnitude of the force exerted on the object.

17. Akhtar, Kiran and Rahul were riding in a motorcar that was moving with a high velocity on an expressway when an insect hit the windshield and got stuck on the windscreen. Akhtar and Kiran started pondering over the situation. Kiran suggested that the insect suffered a greater change in momentum as compared to the change in momentum of the motorcar (because the change in the velocity of the insect was much more than that of the motorcar). Akhtar said that since the motorcar was moving with a larger velocity, it exerted a larger force on the insect. And as a result the insect died. Rahul while putting an entirely new explanation said that both the motorcar and the insect experienced the same force and a change in their momentum. Comment on these suggestions.

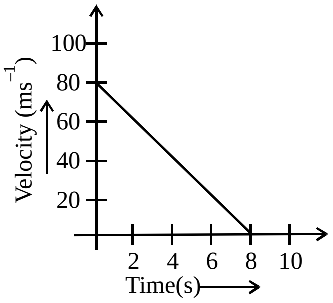
18. How much momentum will a dumb-bell of mass 10 kg transfer to the floor if it falls from a height of 80 cm? Take its downward acceleration to be 10 m s^{-2}.

Exemplar Questions

1. Two balls of the same size but of different materials, rubber and iron are kept on the smooth floor of a moving train. The brakes are applied suddenly to stop the train. Will the ball start rolling? If so, in which direction? Will they move with the same speed? Give reasons for your answer.

2. Two identical bullets are fired-one by a light rifle and another by a heavy rifle with the same force. Which rifle will hurt the shoulder more and why?

3. Velocity versus time graph of a ball of mass 50 g rolling on a concrete floor is shown in Fig. Calculate the acceleration and frictional force of the floor on the ball.



4. Two friends on roller-skates are standing 5 m apart facing each other. One of them throws a ball of 2 kg towards the other, who catches it. How will this activity affect the position of the two? Explain your answer.

5. Using second law of motion, derive the relation between force and acceleration. A bullet of mass 10 g strikes a sand-bag at a speed of 10^3 ms^{-1} and gets embedded after travelling 5 cm. Calculate
   (i) the resistive force exerted by the sand on the bullet
   (ii) the time taken by the bullet to come to rest.

EXERCISE -3 Foundation Builder

Multiple Choice Questions

DIRECTIONS : *This section contains multiple choice questions. Each questions has 4 choices (a), (b), (c) and (d) out of which only one is correct.*

1. A field gun of mass 1.5 t fires a shell of mass 15 kg with a velocity of 150 m/s. Calculate the velocity of the recoil of the gun.
   (a) 1 m/sec (b) 1.5 m/sec
   (b) 3 m/sec (d) 5 m/sec

2. A body of mass 1 kg is kept at rest. A constant force of 6.0N acting on it, the time taken by the body to move through a distance of 12m
   (a) 2 sec (b) 3 sec. (c) 4 sec (d) 5 sec.

3. By applying a force of one Newton, one can hold a body of mass
   (a) 102 gram (b) 102 kg
   (c) 102 mg (d) None of these

4. The speed of a falling body increases continuously, this is because
   (a) no force acts on it
   (b) it is very light
   (c) the air exert the frictional force
   (d) the earth attract it

5. A gun of mass 4.5 kg fires a bullet of mass 20g. with a velocity of 108 km/hr. the recoil velocity of the gun is
   (a) 1.33 m/sec (b) 0.133 m/sec
   (c) 13.3 m/s (d) 133 m/sec

6. A same amount of force is acting on two bodies of different masses 2 kg and 4 kg initially at rest. The ratio of the times required to acquire same final velocity is
   (a) 1 : 1 (b) 1 : 2 (c) 2 : 1 (d) 4 : 16

7. To slow down a car, a braking force of 1200 newtons is applied for 10 seconds. How much force would be needed to produce the same change in velocity in 6 seconds –
   (a) 2000 N (b) 3000 N (c) 2500 N (d) 1500 N

8. A frictionless wagon is pushed from rest, with a force of 60 newtons for 14 seconds. If it then strikes a wall and comes to rest in 0.15 second, how much average force does the wall exert on it ?
   (a) 6000 N (b) 5600 N (c) 4500 N (d) 4000 N

9. A 500 kg rocket is fired straight up from the earth, the engines providing 7500 newtons of thrust. Its acceleration is
   (a) 4.5 m/s^2 (b) 5.2 m/s^2
   (c) 9.8 m/s^2 (d) 15 m/s^2

10. If a jet engine provides a thrust of 45000 newtons, how long must it fire to produce 1 million newton-seconds of impulse ?

(a) 22s (b) 18s (c) 25s (d) 15s

11. What force must the brakes and tires apply to a 2800 kg truck going 30 meters per second to bring it to rest in 8.0 seconds

(a) 12000 N (b) 13000 N
(c) 10500 N (d) 12500 N

12. A 35 kg girl on roller skates, standing still, throws a 6 kg medicine ball forward at 3.5 metes per second. How much is her recoil velocity (the backward speed she acquires as a result of the throw)

(a) – 0.6 m/s (b) – 1.6 m/s
(c) – 2.6 m/s (d) – 5.6 m/s

13. The recoil velocity of a 7.5 kg rifle if it fires an 8.0 gram bullet with a muzzle velocity of 640 meters per second is

(a) 0.12 m/s (b) 0.68 m/s
(c) 2.68 m/s (d) 6.8 m/s

14. A cart weighing 1000 kg was moving with a velocity of 50 km/h on smooth horizontal rails. A mass of 250 kg is dropped into it. The velocity with which it will move is

(a) 2.5 km/h (b) 20 km/h
(c) 40 km/h (d) None of these

15. A rider on horse falls back when horse starts running, all of a sudden because

(a) rider is taken back
(b) rider is suddenly afraid of falling
(c) inertia of rest keeps the upper part of body at rest while lower part of the body moves forward with the horse
(d) none of the above

16. The average force required to stop a ball coming with a momentum of 25 Ns in 0.04 sec is

(a) 625 N (b) 125 N (c) 50 N (d) 25 N

17. A force 10 N acts on a body of mass 20 kg for 10 sec. Change in its momentum is

(a) 5 kg m/s (b) 100 kg m/s
(c) 200 kg m/s (d) 1000 kg m/s

18. A force of 8 N acts on an object of mass 5 kg in X-direction and another force of 6 N acts it in Y-direction. Hence the magnitude of acceleration of the object will be

(a) 1.5 m/s^2 (b) 2 m/s^2
(c) 2.5 m/s^2 (d) 3 m/s^2

19. When forces F_1, F_2 and F_3 are acting on a particle of mass m such that F_2 and F_3 are mutually perpendicular, then the particle will remain stationary. If force F_1 is removed the acceleration of the particle will be

(a) $\frac{F_1}{m}$ (b) $\frac{F_2}{m}$ (c) $\frac{F_3}{m}$ (d) None

20. The average force necessary to stop a hammer having momentum 25 N-s in 0.05 second is

(a) 25 N (b) 50 N (c) 1.25 N (d) 500 N

21. A force of 100 dynes acts on mass of 5gm for 10 sec. The velocity produced is

(a) 2 cm/sec (b) 20 cm/sec
(c) 200 cm/sec (d) 2000 cm/sec

22. A stone is tied with a string and a uniform circular motion is development in the stone. If the string breaks down the stone moves in direction:

(a) Radially inward (b) Radially outward
(c) Tangentially outward (d) Tangentially inward

23. A cart of mass M moves at a speed u on a frictionless surface. At regular intervals of length L, blocks of mass $m = \frac{M}{2}$ drops vertically into the cart. How much time is taken to cover a distance $\frac{9}{2}L$ of ?

(a) $\frac{9L}{2u}$ (b) $\frac{5L}{2u}$ (c) $\frac{19L}{2u}$ (d) $\frac{17L}{2u}$

24. A machine gun fires n bullets per second, each of mass m. If the speed of each bullet is v. then the force of recoil is

(a) mng (b) mnv
(c) mnvg (d) $\frac{\text{mnv}}{\text{g}}$

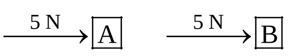
25. In an hour-glass approximately 100 grains of sand fall per second (starting from rest), and it takes 2 sec for each sand particle to reach the bottom of the hour-glass. If the average mass of each sand particle is 0.2 g then the average force exerted by the falling sand on the bottom of the hour-glass is close to.

(a) 0.4 N (b) 0.8 N (c) 1.2 N (d) 1.6 N

26. A machine gun fires a bullet of mass 40 gram at a speed of 1200 ms^{-1}. The man holding it can exert a maximum forces of 144 N on the gun. How many bullets can he fire per second at the most?

(a) One (b) Four (c) Two (d) Three

27. Two forces of equal magnitude 5 N act on two isolated objects A and B as shown in figure. The acceleration of B is three times that of body A. the mass A is



(a) Three times that of B (b) One third to that of B
(c) Nine times to that of B (d) One ninth to that of B.

28. A body of mass M hits normally a rigid wall with velocity u and bounces back with the same velocity.

The change in momentum is

(a) 2 Mu (b) Mu
(c) Zero (d) Mu/ 2

More than One Option Correct

DIRECTIONS : *This section contains multiple choice questions each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE may be correct.*

1. Acceleration of a body can be calculated using

(a) $a = F/m$ (b) $a = \dfrac{v-u}{t}$

(c) $a = P/m$ (d) $a = s/t$

2. Which physical quantity has its unit as 'Newton' ?

(a) Friction (b) Acceleration

(c) Force (d) Momentum

3. The acceleration produced by a force of 5 N on a mass of 10 kg is

(a) 5 m/s^2 (b) 2 m/s^2

(c) 0.5 ms^{-2} (d) 50 cm s^{-2}

4. What force would be required to produce an acceleration of 4m/s^2 in a ball of mass 6 kg ?

(a) 24 N (b) 42 N

(c) 42 kg m/s^2 (d) 24 kg m/s^2

Passage/Case Based Question

DIRECTIONS : *Read the passage (s) given below and answer the questions that follow.*

1. Two toy cars A and B are moving towards each other on a horizontal surface. The car A has mass of 60 g and moves towards right with a speed of 120 cms^{-1}. The car B has a mass of 100 g and moves towards the left with a speed of 50 cms^{-1}. The two cars collide and get stuck to each other.

A B

(i) Momentum of the cars A and B before collision in g cms^{-1} is:

(a) 7200, –5000 (b) 3600, 2000

(c) 3600, 1000 (d) 3200, 1600

(ii) Velocity of the cars with which they move after collision is:

(a) 20 m/s (b) 13.75 m/s

(c) 10 m/s (d) 5 m/s

(iii) After collision the cars will move towards:

(a) right

(b) left

(c) either right or left

(d) None of these

Assertion & Reason Questions

DIRECTIONS : *The questions in this segment consists of two statements, one labelled as "Assertion A" and the other labelled as "Reason R". You are to examine these two statements carefully and decide if the Assertion A and Reason R are individually true and if so, whether the reason is a correct explanation of the assertion. Select your answers to these items using the codes given below.*

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true but R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false but R is true.

1. **Assertion (A):** When a bullet is fired from a gun, there is a forward force on the bullet and recoil of gun.

Reason (R): Every action has an equal and opposite reaction.

2. **Assertion (A):** When astronauts throw something in space, that object would continue moving in the same direction and with the same speed.

Reason (R): The acceleration of an object produced by a net applied force is directly related to the magnitude of the force, and inversely related to the mass of the object.

3. When we sit on a chair, our body exerts a force downward and

Assertion (A): That chair needs to exert an equal force upward or the chair will collapse.

Reason (R): The third law says that for every action there is an equal and opposite reaction.

4. **Assertion (A):** A quick collision between two bodies is more violent than a slow collision, even when the initial and the final velocities are identical.

Reason (R): Because the rate of change of momentum which determines the force is greater in the first case.

5. **Assertion (A):** Change in momentum is impulse.

Reason (R): Impulse is the area between (F – t) curve and time axis.

6. **Assertion (A):** Same force applied for the same time causes the same change in momentum for different bodies.

Reason (R): The total momentum of an isolated system of interacting bodies remains conserved.

Multiple Matching Question

DIRECTIONS : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r and s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in column I with entries in column II.*

1. | | Column I | | Column II |
|---|---|---|---|
| (A) | Newton's first law | (p) | impulse |
| (B) | *Ft* | (q) | rocket propulsion |
| (C) | Newton's third law | (r) | mass × velocity |
| (D) | Newton's second law | (s) | inertia |
| (E) | Linear momentum | (t) | $F = ma$ |

	A	B	C	D	E
(a)	s	p	q	t	r
(b)	p, q, r, s	q	p, q, r, s	p, q, r, s	r, s
(c)	r, t	u, s	p, r	p, r	t
(d)	p,	q, r	r	s	p

Numeric/Integer Type Questions

1. A motor car of mass 1200 kg is moving along a straight line with a uniform velocity of 90 km/h. Its velocity is slowed down to 18 km/h in 4s by an unbalanced external force. Calculate the acceleration (in m/s^2)
2. By how much does the momentum of a body of mass 5 kg change when its speed decreases from 20 m/s to 0.20 m/s.
3. Calculate the mass of the body, when a force of 525 N, produces an acceleration of 3.5 m/s^2.
4. Which would require a greater force accelerating a 2 kg mass at 5 ms^{-2} or a 4 kg mass at 2 ms^{-2}
5. A man pushes a box of mass 50 kg with a force of 80 N. What will be the acceleration of the box due to this force?
6. For how long should a force of 100 N act on a body of mass 20 kg initially at rest so that it acquires a velocity of 100 m/s?
7. A car of mass 800 kg travelling at a speed of 10 ms^{-1} is brought to rest in 20 seconds by applying brakes. Calculate the average braking force acting on the wheels.
8. A bullet of mass 10 g is fired at a speed of 400 ms^{-1} from the gun of mass 4 kg. What is the recoil of the gun ?
9. A 40 kg shell is lying at a speed of 72 km/h. It explodes into two pieces, one piece of mass 15 kg stops. Calculate the velocity of the other piece.
10. A bullet of mass 10g is fired with a rifle. The bullet takes 0.003 s to move through its barrel and leaves it with a velocity of 300 m/s. What is the force exerted on the bullet by the rifle ?
11. A force produces an acceleration of 16 m/s^2 in a body of mass 0.5 kg, and an acceleration of 4 m/s^2 in another body. If both the bodies are fastened together, then what is the acceleration produced by that force?
12. A 20 gm bullet moving at 300 m/s stops after penetrating 3 cm of bone. Calculate the average force exerted by the bullet.
13. A force of 50 N is inclined to the vertical at an angle of 30°. Find the aceeleration it produces in a body of mass 2 kg which moves in the horizontal direction on smooth surface.
14. A gun weighing 10 kg fires a bullet of 30 g with a velocity of 330 m/s. With what velocity does the gun recoil? What is the resultant momentum of the gun and the bullet before and after firing?

SOLUTIONS

Brief Explanations of Selected Questions

Let's Revise Through FIB & T/F

1.	newton	2.	forward
3.	mass	4.	True
5.	True	6.	True
7.	net unbalanced	8.	True
9.	False	10.	True
11.	True	12.	False
13.	impulse	14.	impulse
15.	impulse	16.	True
17.	True	18.	equal, opposite
19.	True	20.	False

EXERCISE-1 **Master Board**

Multiple Choice Questions

1. (d) Newton' first law of motion is also called law of inertia as it defines inertia.
2. (c) The body will continue accelerating until the resultant force acting on the body becomes zero.
3. (c)
4. (c) From Newton's second law if $\Sigma F_i = 0$ then the body is in translational equilibrium.
5. (b) $F = \frac{dp}{dt}$
6. (b) Inertia is resistance to change.
7. (c) He can come at shore by making use of Newton's third law. In this case man push the ice backward & ice reacts back to the man in forward direction due to friction between ice & man. If friction is very small between him & the ice, then he come out from this pond only by taking very small steps.
8. (c) The gun applied a force F_{12} on the bullet in forward direction & according to Newton's third law bullet applies a reaction force on gun F_{21} in backward direction. But the recoil speed of gun is very low in comparison to bullet due to large mass.
9. (b) When jet plane flies, it ejects gases in back ward direction at very high velocity. From Newton's third law, these gases provides the momentum to jet plane in forward direction plus compensates the force of gravity.
10. (b) 11. (a) 12. (a) 13. (c)
14. (b) $a = \frac{v-u}{t}$ or $a = \frac{v^2-u^2}{25}$

$$\Rightarrow \frac{25-400}{2\times 100} = \frac{-375}{200}$$

$$F = ma = 20 \times \frac{-375}{200} = -37.5\text{ N}$$

15. (d) 16. (c) 17. (a) 18. (a) 19. (a)
20. (d) Inertia of a body depends on mass, higher the mass higher will be inertia.

Assertion & Reason Questions

1. (a) According to Newton's second law of motion$a = \frac{F}{m}$
i.e. magnitude of the acceleration produced by a given force is inversely proportional to the mass of the body. Higher is the mass of the body, lesser will be the acceleration produced i.e. mass of the body is a measure of the opposition offered by the body to change a state, when the force is applied i.e. mass of a body is the measure of its inertia.
2. (c) According to Newton's second law.
Acceleration $= \frac{\text{force}}{\text{mass}}$ i.e. if net external force on the body is zero then acceleration will be zero.
3. (c) A cricket player moves his hands backward to increase the time interval for reducing the momentum of the ball to zero. Thus the ball does not hit him hard as force is directly proportional to change of momentum.
4. (d) 5. (b)

Multiple Matching Questions

1. (A) → (q); (B) → (r); (C) → (p); (D) → (s)
2. (A) → q; (B) → p; (C) → r; (D) → s

Passage/Case Based Question

1. (i) (b) The force of action and reaction acts on different bodies.
(ii) (c) Recoiling of a cannon after firing a shot is an example of Newton's Third law.

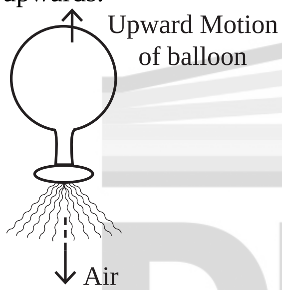
Very Short Answer Questions

1. 10 kg-wt.
2. When the force applied on a body is zero, Newton's first law becomes a special case of Newton's second law.
3. $F = -m \times a$ or $-F = m \times a$
4. If passangers do not wear seat belts while travelling in a car and if they meet with a road accident then the large force on the body of passangers produced by rapid decrease in momentum can throw the passangers forward violently as travelling car stops suddenly due to an accident causing serious injuries.
5. No, it is the unbalanced force i.e., the resultant of all the forces acting on a body is not zero. Unbalanced force can produce motion in a stationary object but cannot change the shape of the object. When unbalanced forces act on a body, they produce a change in its state of rest or of uniform motion.

6. An athlete is advised to come to stop slowly after finishing a fast race, so that time of stop increases and hence force experienced by him decreases.
7. The other team falls backwards due to an unbalanced force acting on the team if one of the teams suddenly releases the rope in a game of a tug of war.

Short Answer Questions

1. Refer to theory
2. Refer to theory
3. Refer to theory
4. Refer to theory
5. Refer to theory
6. Yes, when the inflated balloon is released with its mouth in the downward direction, then the air rushes out of balloon in the downward direction and according to Newton's third law of motion, the equal and opposite reaction of downward going air pushes the balloon upwards.



7. To move or accelerate a horse-cart system, the forward reaction to the backward push of the horse is greater than the opposing frictional forces of the wheels.
If M = mass of horse, m = mass of cart, H = horizontal component of reaction and F = force of friction, then acceleration of a horse-cart system,

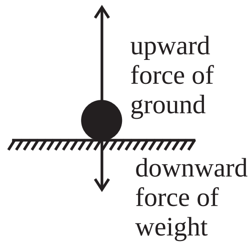
$$a = \frac{H - F}{M + m}$$

Long Answer Questions

1. Two major forces act on the water skier, one of these forces is that exerted on her hands by the towrope. The other is the resistance of the water (and to a lesser extent the air). When the skier is moving in a straight line at a constant 15 km/h, her velocity is constant. According to Newton's first law, the net force on the skier must be zero. Indeed, the law itself is the basis for asserting that the force exerted by the water and the air on the skier is exactly equal in magnitude, and opposite in direction, to that exerted on her by the towrope.
When the skier is moving at 20 km/h, the force exerted on her by the towrope is greater in magnitude than that at 15 km/h.
But so is the resistive force. Again, the net force on the skier must be zero because her velocity is constant.
2. Refer to theory
3. Refer to theory

HOTS Questions

1. When our hand turns the handle of a faucet, the faucet in turn applies a pressure on our fingers. These two forces i.e, the push of our hand on the handle of the tap and the push of the tap on our hand make the action-reaction pair.
When force is applied by our hand turns the faucet which moves the screw inside the tap and releases the water which flows out of the nozzle of the tap. The force of screw of the tap on the water and force of water on it make another action-reaction pair. But this means that our push on the handle and the water coming out of the tap do not make an action-reaction pair since our hand and water is not touching each other.
2. (a) The figure shows a stone resting on the ground. The net force on the stone is zero as its acceleration is zero. One of the force that acts on stone is the weight force of the stone, due to earth's gravitational pull, acting in the downward direction. This force acts on the ground and pushes it down. As a reaction to this force the ground also exerts an equal and opposite force on the stone in the upward direction. As a result the two forces cancel and no net force acts on the stone. The force vectors can be represented as shown in figure 1.



(b) The downward weight force is balanced by an upward force. This upward force is conventionally called reaction force of the ground that prevents the ground from sinking and keeps the stone at rest. It acts normal to the surface of the ground.

EXERCISE-2 **NCERT Questions**

In-text Book Questions

1. (a) a stone (b) a train (c) a five rupee coin
Reason for all three cases is the same. Greater the mass greater is the inertia.
2. Before shaking the branches, leaves are at rest. When branches are shaken, they come in motion while the leaves tend to remain at rest due to inertia of rest. As a result leaves get detached from the branches and fall down.
3. When a moving bus brakes to a stop, the lower part of our body in contact with the bus comes to rest while the upper part of our body tends to keep moving due to inertia of motion. Hence we fall forwards. When the bus accelerates from rest, the lower part of our body comes into motion along with the bus while the upper part of body tends to remain at rest due to inertia of motion. Hence we fall backwards.

4. The horse pulls the cart with a force (action) in the forward direction. The cart also pulls the horse with an equal force (reaction) in the backward direction. While pulling the cart, the horse pushes the ground with its feet in the backward direction, the reaction of the earth makes it move in the forward direction alongwith the cart. Here action is on the ground while the reaction on the horse.

5. It is difficult for a fireman to hold a hose because the water is ejected out in the forward direction with a large force due to which same force is developed in the hose in the opposite direction and therefore hose is pushed in the backward direction. Thus, it becomes difficult for a firemean to hold a hose.

6. Mass of bullet, m_1 = 50 g = 0.05 kg
Mass of rifle, m_2 = 4 kg
Initial velocity of bullet, $u_1 = 0$
Initial velocity of rifle, $u_2 = 0$
Final velocity of bullet, $v_1 = 35\ ms^{-1}$
Recoil velocity of rifle, v_2 = ?
According to the law of conservation of momentum,
Total momenta after firing = Total momenta before firing

$$m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$$

$$0.05 \times 35 + 4v_2 = 0 + 0$$

$$v_2 = -\frac{0.05 \times 35}{4} = -\frac{7}{16} = -0.44\ ms^{-1}$$

The negative sign indicates that the direction in which the rifle would recoil is opposite to that of the bullet.

7. Here, m_1 = 100 g = 0.1 kg, m_2 = 200 g = 0.2 kg, $u_1 = 2ms^{-1}$, $u_2 = 1ms^{-1}$, $v_1 = 1.67\ ms^{-1}$, v_2 = ?
According to the law of conservation of momentum.
Total momenta = Total momenta
before collision after collision

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

or $0.1 \times 2 + 0.2 \times 1 = 0.1 \times 1.67 + 0.2v_2$

or $0.4 = 0.167 + 0.2\ v_2$

or $v_2 = \dfrac{0.4 - 0.167}{0.2} = 1.165\ ms^{-1}$

Text-Book Exercise

1. Yes, an object may travel with a non-zero velocity even when the net external force on it is zero. A rain drop falls down with a constant velocity. The weight of the drop is balanced by the upthrust and the viscosity of air. The net force on the drop is zero.

2. When we beat the carpet with a stick, it comes into motion. But the dust particles continue to be at rest due to inertia and get detached from the carpet.

3. Due to sudden jerks or due to the taking sharp turn on the road, the luggage may fall down from the roof because of its tendency to continue moving in the original direction. To avoid this, the luggage is tied with a roap on the roof.

4. **(c)** Force of friction acts on the ball in the opposite direction hence it comes to rest.

5. Here, u = 0, s = 400m, t = 20s

$\therefore$ $s = ut + \frac{1}{2}at^2$

or $400 = 0 + \frac{1}{2}a(20)^2$

or $a = \dfrac{400 \times 2}{400} = 2\ m/s^2$

Now m = 7 metric tonne = 7000 kg, $a = 2\ m/s^2$
$\therefore$ Force, F = ma = 7000 × 2 = 14,000 N

6. Here, m = 1kg, $u = 20\ ms^{-1}$, $v = 0$, s = 50m
As $v^2 - u^2 = 2as$
$\therefore$ $0^2 - 20^2 = 2a \times 50$

or $a = -\dfrac{400}{100} = -4\ ms^{-2}$

Force of friction, F = ma = 1 × (–4) = –4 N

7. Total mass of engine and 5 wagons,
m = 8,000 + 5 × 2,000 = 18,000 kg
(a) The net accelerating force,
F = force exerted by engine – friction force
= 40,000 – 5,000 = 35000 N.
(b) The acceleration of the train.

$$a = \frac{F}{m} = \frac{35{,}000}{18{,}000} = \frac{35}{18} = 1.94\ ms^{-2}$$

8. Here m = 1,500 kg, a = $-1.7\ ms^{-2}$
= ma = 1,500 × (–1.7) = –2,550 N
The force between the vehicle and the road is 2550 N, in a direction opposite to the direction of the motion of the vehicle.

9. **(d)** mv

10. The cabinet will move with constant velocity only when the net force on it zero.
$\therefore$ Force of friction on the cabinet = 200 N, in a direction opposite to the direction of motion of the cabinet.

11. Here, $m_1 = m_2 = 1.5$ kg, $u_1 = 2.5ms^{-1}$,
$u_2 = -2.5\ ms^{-1}$
Let v be the velocity of the combined object after the collision. By conservation of momentum,
Total momenta after collision = Total momenta before collision.

$$(m_1 + m_2)v = m_1u_1 + m_2u_2$$

$$(1.5 + 1.5)\ v = 1.5 \times 2.5 + 1.5 \times (-2.5)$$

$3.0\ v = 0$ or $v = 0\ ms^{-1}$

12. Action and reaction always act on different bodies, so they do not cancel each other. When we push a massive truck, the force of friction between its tyres and the road is very large and the force exerted by push is not sufficient to over come that force so the truck does not move.

13. Here, m = 200 g = 0.2 kg, u = $10ms^{-1}$, v = – $5ms^{-1}$
Change in momentum = $m(v-u)$
$= 0.2(-5-10) = -3$ kg ms^{-1}

14. Here, $m = 10$, $g = 0.01$ kg, $u = 150$ ms^{-1}, $v = 0$,
$t = 0.03$ s

$$a = \frac{v-u}{t} = \frac{0-150}{0.03} = -5000ms^{-2}$$

The distance of penetration of the bullet into the block,

$$s = ut + \frac{1}{2}at^2 = 150 \times 0.03 + \frac{1}{2} \times (-5000) \times (0.03)^2$$

$= 4.5 - 2.25 = 2.25$ m

The magnitude of the force exerted by the wooden block on the bullet.
= ma = 0.01 × 5000 = 50 N.

15. Here, $m_1 = 1$ kg, $u_1 = 10$ ms^{-1}, $m_2 = 5$ kg, $u_2 = 0$
Let v be the velocity of the combined object after the collision.
Total momentum just before the impact $= m_1u_1 + m_2u_2$
$= 1 \times 10 + 5 \times 0 = 10$ kg ms^{-1}
Total momentum of the combined object just after the impact.
$= (m_1 + m_2)v = (1 + 5)v = 6v$ kg ms^{-1}
By conservation of momentum,
Final momentum = Initial momentum
$6v = 10$

or $v = \frac{10}{6} = \frac{5}{3}$ ms^{-1}

∴ Total momentum just after the impact

$= 6 \times \frac{5}{3} = 10$ kg ms^{-1}

16. Here, $m = 100$ kg, $u = 5$ ms^{-1}, $v = 8ms^{-1}$, $t = 6$s
Initial momentum,
$p_1 = mu = 100 \times 5 = 500$ kg ms^{-1}
Final momentum,
$p_2 = mv = 100 \times 8 = 800$ kg ms^{-1}
The magnitude of the force exerted on the object,

$$F = \frac{p_2 - p_1}{t} = \frac{800-500}{6} = \frac{300}{6} = 50N$$

17. Rahul gave the correct explanation. According to Newton's 3rd law both the motorcar and insect experience the equal force and hence a same change in their momentum. Due to smaller mass or inertia, the insect dies. The mass of motor car is much larger so there is little change in its velocity.

18. Here, $m = 10$ kg, $u = 0$, $h = 80$ cm = 0.80 m,
$a = 10$ ms^{-2}
Let v be the velocity gained by the dumb-bell as it reaches the floor.
As $v^2 - u^2 = 2ah$
∴ $v^2 - 0^2 = 2 \times 10 \times 0.80 = 16$
or $v = 4$ ms^{-1}
Momentum transferred by the dumb-bell to the floor
$p = mv = 10 \times 4 = 40$ kg ms^{-1}

Exemplar Questions

1. Yes, the ball will start rolling in the direction in which the train was moving. Due to the application of the brakes, the train comes to rest but due to inertia the balls remain in motion, therefore, they begin to roll. Since the masses of the balls are not the same, therefore, the inertial forces are not same on both the balls. Thus, the balls will move with different speeds.
2. From the light rifle, according to law of conservation of momentum or explanation of Newton's laws of motion.
3. Acceleration

$$a = \frac{v-u}{t} = \frac{80}{8}ms^{-2} = 10\ ms^{-2}$$

Force = ma = $\frac{50}{1000} \times 10 = 0.5$ N

4. Seperation between them will increase. Initially the momentum of both of them are zero as they are at rest. In order to conserve the momentum the one who throws the ball would move backward. The second will experience a net force after catching the ball and therefore will move backwards that is in the direction of the force.
5. (i) $m = 10$ g $= \frac{10}{1000}$ kg
$v = 10^3$ m/s
$v = 0$
$s = \frac{5}{100}$ m
$v^2 - u^2 = 2as$

$$0-(10^3)^2 = 2.a.\frac{5}{100}$$

$$a = \frac{-1000 \times 1000}{10} \times 100 = -10^7\ ms^{-2}$$

$F = m.a = 10^5$ N

(ii) $v = u + at$
$0 = 10^3 - 10^7t$
$10^7t = 10^3$

$$\Rightarrow t = \frac{10^3}{10^7} = 10^{-4}s$$

EXERCISE-3 **Foundation Builder**

Multiple Choice Questions

1. (b) 2. (a) 3. (a) 4. (d) 5. (b)
6. (b) $v = at \Rightarrow a_1t_1 = a_2t_2$

$$\Rightarrow \frac{t_1}{t_2} = \frac{a_2}{a_1} = \frac{F/m_2}{F/m_1} = \frac{m_1}{m_2} = \frac{2}{4} = \frac{1}{2}$$

7. (a) 8. (b) 9. (d) 10. (a) 11. (c)
12. (a) 13. (b)

14. (c) $mu = (m + m')v$
$1000 \times 50 = 1250 \times v$
$\Rightarrow \quad v = 40$ km/h

15. (c)

16. (a) $F_{net} = \frac{\Delta\vec{p}}{\Delta t} = \frac{0-25}{0.04} = \frac{-25\times 100}{4} = 625$ N

17. (b)

18. (b) $F_x = 8$ N $\quad F_y = 6$ N
$F_{net} = \sqrt{8^2+6^2} = 10$ N
10 N $= 5 \times a \Rightarrow a = 2$ m/s^2

19. (a) $F_1 = \sqrt{F_2^2 + F_3^2} \Rightarrow F_{net} = 0$
When F_1 is removed $F_{net} = \sqrt{F_2^2+F_3^2}$
$\therefore \quad a = \sqrt{\frac{F_2^2+F_3^2}{m}} = \frac{F_1}{m}$

20. (d) 21. (c)

22. (c) Stone will follow its direction of motion i.e. tangential.

23. (d) 24. (b)

25. (a) Velocity of sand particle just before striking the bottom
$v = u + at \Rightarrow v = 0 + 10 \times 2 = 20$ m/s
[$\because u = 0$ and $t = 2$s given]
Initial momentum, $pi = mV = (0.2 \times 10^{-3}) \times 20$
Final momentum, $pf = 0$ [$\because$ final velocity = 0]
$|\Delta p| = P_i - P_f = 4 \times 10^{-3}$ k-m/s
Rate of change of momentum $\frac{|\Delta p|}{\Delta t}$ = force exerted by falling sand
$\therefore \quad f_{avg} = \frac{|\Delta p|}{\Delta t} \times n = \frac{4\times 10^{-3}\times 100}{1}$
or, $f_{avg} = 0.4$ N

26. (d) Given,
Mass of the bullet, $m = 40$ g
Speed of the bullet, $v = 1200$ ms^{-1}
Let he can fire n bullets per second.
Force = $m \times v \times n$
$\Rightarrow \quad 144 = \frac{40}{1000} \times 1200 \times n \Rightarrow n = 3$

27. (a) $F_A = F_B$
$M_A a_A = M_B a_B$
$M_A a_A = M_B 3a_A$.
$M_A = 3M_B$
$\therefore$ Mass of A is three times that of B

28. (a) Initial momentum of body = Mu
Final momentum of body = – Mu (negative sign is taken due to change in direction of motion)
$\therefore$ Change in momentum = Mu – (–Mu) = 2Mu

More than One Option Correct

1. (a, b) 2. (a, c) 3. (c, d) 4. (a, d)

Passage/Case Based Question

1. (i) (a) Let us take the direction towards the right as positive direction. The linear momentum of a before the collision is
$P_1 = m_1v_1 = 60 \times 120 = 7200$ g cms^{-1} and that of B is
$P_2 = m_2v_2 = 100 \times (-50) = -5000$ gcms^{-1}
The total momentum of A and B before collision is
$P = P_1 + P_2 = 7200 - 5000 = 2200$ gcms^{-1}
(ii) (b) Let the velocity just after collision be v. The total momentum
$m_1v + m_2v = (160 \text{ g})\, v$
By the law of conservation of momentum
2200 gcms^{-1} = (160 g)v
$v = 13.75$ ms^{-1}
(iii) (a) As v comes out to be positive, the cars move together towards the right.

Assertion & Reason Questions

1. (a) 2. (b) 3. (a) 4. (a) 5. (b)

6. (b) According to 2nd law of motion;
$F_1 = \frac{\Delta P_1}{\Delta t_1} \qquad F_2 = \frac{\Delta P_2}{\Delta t_2}$
$\therefore \quad F_1 \times \Delta t_1 = F_2 \times \Delta t_2$
$\Rightarrow \quad \Delta P_1 = \Delta P_2$
Thus the same force for the same time causes the same change in momentum for different bodies.

Multiple Matching Question

1. (a) (A) → (s); (B) → (p); (C) → (q); (D) → (r); (E) → (r)

Numeric/Integer Type Questions

1. –5ms^{-2}
2. –99 kg m/s
3. 150 kg
4. 2 kg mass at 5 ms^{-2}
5. 1.6 m/s^2
6. 20 s
7. Average braking force = – 400 N.
8. The gun recoils with a velocity of 1 ms^{-1} in the direction opposite to that of the bullet.
9. 32 m/s
10. 10^3 N
11. 3.2 m/s^2
$a_1 = 16$ m/s^2, $m_1 = 0.5$ kg,
$F = m_1a_1 = 16 \times 0.5$ kg $= 8$ N

$$ma_2 = \frac{F}{a_2} = \frac{4}{8} = 2\text{ kg} ; m_1 + m_2 = 0.5 + 2 = 2.5\text{ kg},$$

$$F = 8\ N;\quad a = \frac{F}{m_1 + m_2} = \frac{8}{2.5} = 3.2\ \text{m/s}^2$$

12. -3×10^4 N

Hints: $m = \frac{20}{1000}$ kg, $u = 300$ m/s, $v = 0$, $s = 3$ cm $= 3 \times 10^{-2}$ m

$$\therefore\quad a = \frac{v^2 - u^2}{2s} = \frac{0-(300)^2}{2\times3\times10^{-2}} = \frac{-300\times300}{2\times3\times10^{-2}}$$

$= -1.5 \times 10^6$ m/s^2

$$\therefore\quad F = ma = \frac{20}{1000}\times(-1.5\times10^6) = -3 \times 10^4\text{ N}$$

13. 12.5 m/s^2

Hints: Horizontal component of force = F sin θ

$$\Rightarrow\ a = \frac{F\sin\theta}{m} = \frac{50\sin30°}{2} = 12.5\text{m/s}^2$$

14. – 0.99 m/s, zero before and after firing

Hints: M = 10 kg, m = $\frac{30}{1000}$ kg., V = ?, v = 330 m/s

From conservation of momentum, MV + mv = 0

$$\Rightarrow 10 \times V = -\frac{30}{1000}\times330 \ \Rightarrow V = -0.99\text{ m/s}$$

Resultant momentum before and after firing is zero as no external froce is acting on it.